

ASTRONOMY

November 1983

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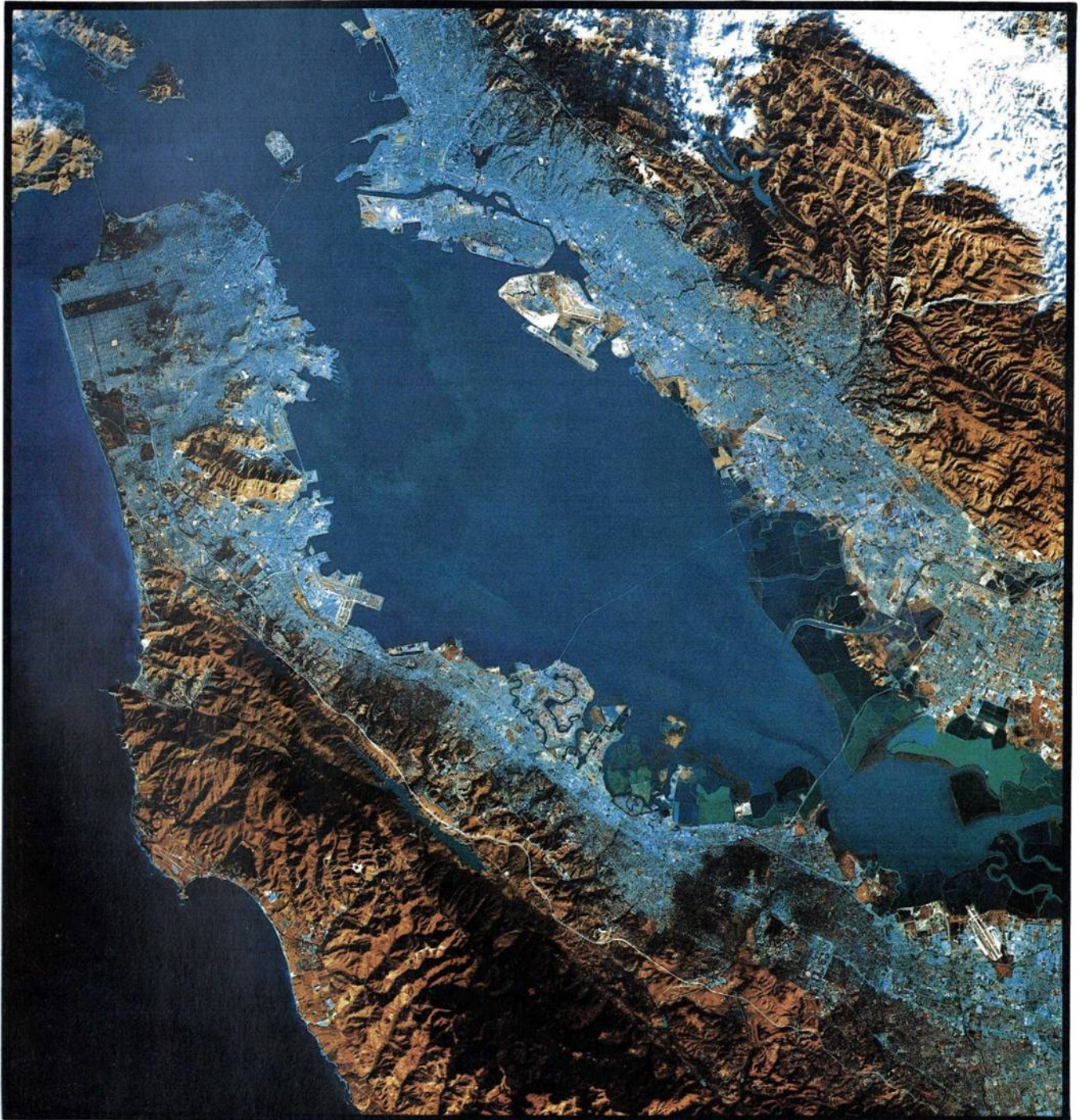
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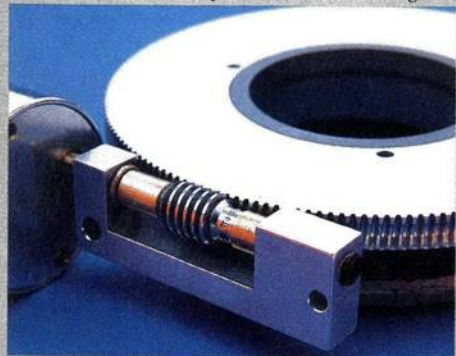


Meade Model 2080: 8" Schmidt-Cassegrain Telescope. (Shown with optional Rotary Eyepiece Holder.)

Meade Schmidt-Cassegrains are now the leading instruments of their type throughout the World, and for one reason: precision. Precision in design, in engineering, and in manufacture. And, now Meade Instruments backs up this commitment to precision with a **Warranty valid for as long as you own your telescope.**

Consider the following technical advantages — advantages that have made Meade Schmidt-Cassegrains Number One worldwide.

Optical Design and Manufacture — Meade 4", 8", and 10" optical system designs utilize the latest, most modern computer-aided ray trace analysis. Analysis which showed us, for example, that by making the primary mirrors of Meade 8" and 10" Schmidt-Cassegrains 3% oversize, we could increase off-axis image brightness by 10% over competing models, aperture for aperture. As a result, the 8" Meade 2080 **without** high transmission coatings yields brighter off-center images than competing 8" telescopes **with** coatings. The 10" Meade 2120 yields off-center images almost as bright as competing



11" models, but with vastly superior portability and at substantially lower cost.

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Latitude scale of the Equatorial Wedge.

Advanced-Design Equatorial Wedge and Field Tripod Systems

The owner of a Meade Schmidt-Cassegrain will appreciate the attention to detail shown in the Meade Equatorial Wedge and Field Tripod. Each Wedge includes a latitude scale permitting accurate polar alignment of the telescope in a few **seconds**, not minutes. A universal bubble level, machined into the floor of the Wedge and also included as standard equipment, enables the observer to rapidly align the wedge/tripod system to the horizontal, without guesswork. Azimuth orientation is facilitated by the 360°-rotation capability of the Wedge on the Field Tripod — and by the fact that no wrenches or tools of any kind are required in the operation of 4" and 8" models, and only one hex wrench on 10" models.



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Systems Engineering — Meade Schmidt-Cassegrain telescopes and their long list of related optional accessories were designed as a system of complementary components. The optional electric declination motor,

(1) Bubble level; (2) Latitude scale; (3) No-Tool-Required adjustment knobs; (4) Wedge-to-Tripod lock knob, permitting 360° Wedge adjustments in azimuth.

for example, fits neatly in a cavity at the undersurface of one fork arm. Optional dew shields lock into a track pre-machined into the corrector cell of every 8" and 10" telescope. Other accessory systems, from sliding counterweights to the f/2.64 Schmidt Camera, attach directly to the standard telescopes without customer drilling or adaptation. The motivated observer will find an almost unlimited potential for growth, with an absolute minimum of observing time diverted to equipment maintenance and adjustment.



Great Nebula in Orion (M42). A 50-minute exposure on Ektachrome 400 through the Meade 8" Model 2080.

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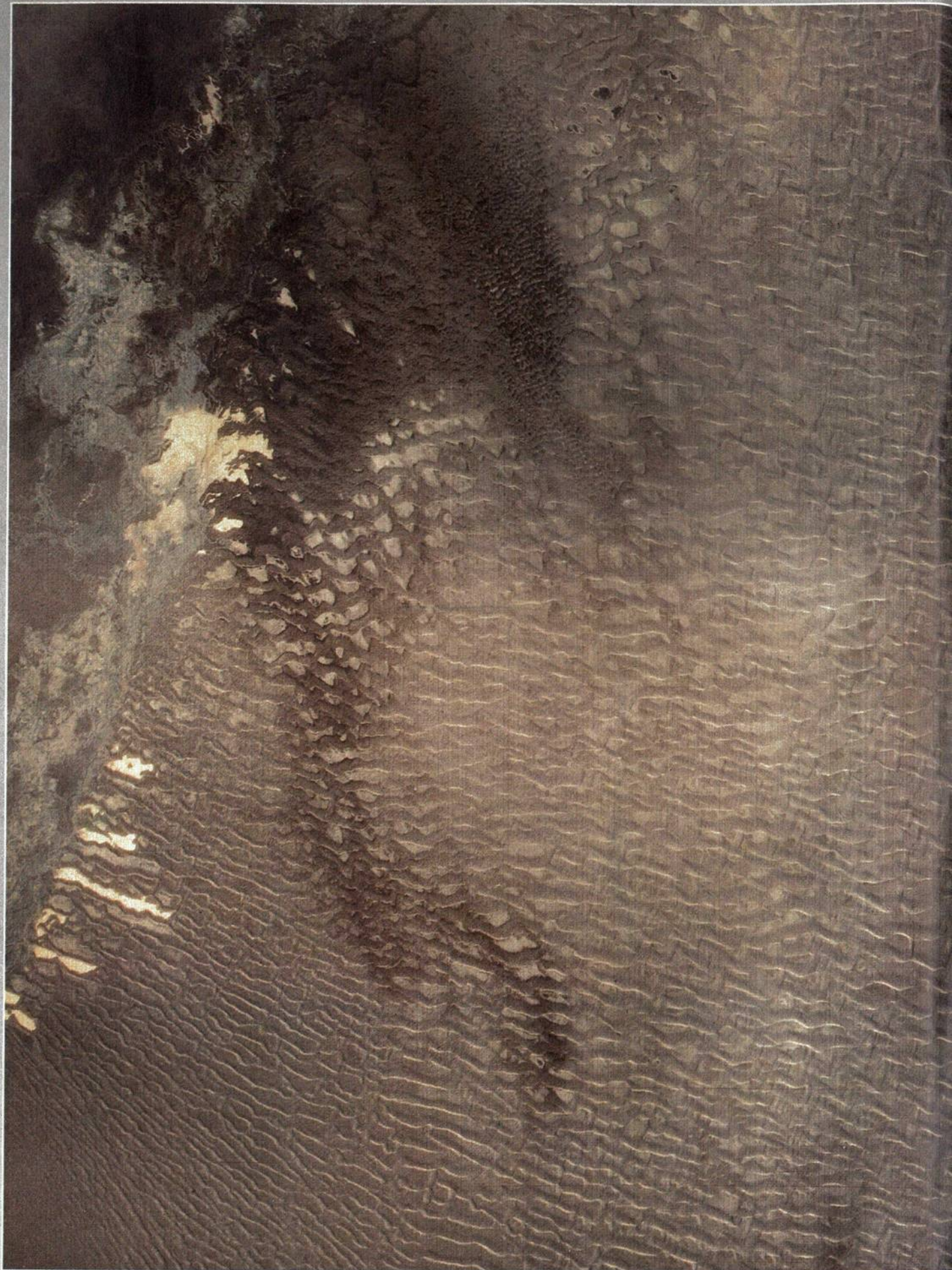
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ASTRONOMY

Vol. 11, No. 11

November 1983

The World's Most Beautiful Astronomy Magazine • Established by Stephen A. Walther

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Canadian Newsstand Dist.

Distr. Div. of TV GUIDE

112 Merton St.

Toronto, Ontario M4S 2Z7

World Newsstand Distribution

Boarts International, Inc.

1633 Broadway

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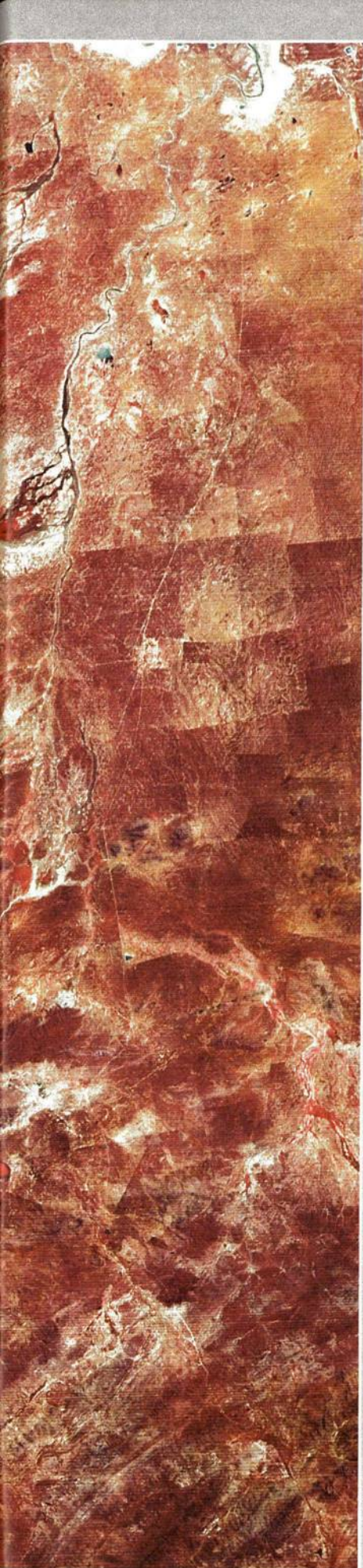
Cover: From 440 miles above San Francisco Bay, Landsat 4's thematic mapper recorded this false-color image on December 31, 1982. Among the features visible are the cities of San Francisco and Oakland, many airports, two lakes along the San Andreas fault, clouds filling valleys east of Oakland, and the shallow mud bottom of the bay itself. These pages: Dunes in the Takla Makan desert in Sinkiang, China. This month's lead feature explores the role that terrestrial geology plays in furthering our understanding of other bodies in the solar system — and showcases a portfolio of spacecraft images of Earth. NASA/Goddard photos.

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Geology *from* Space

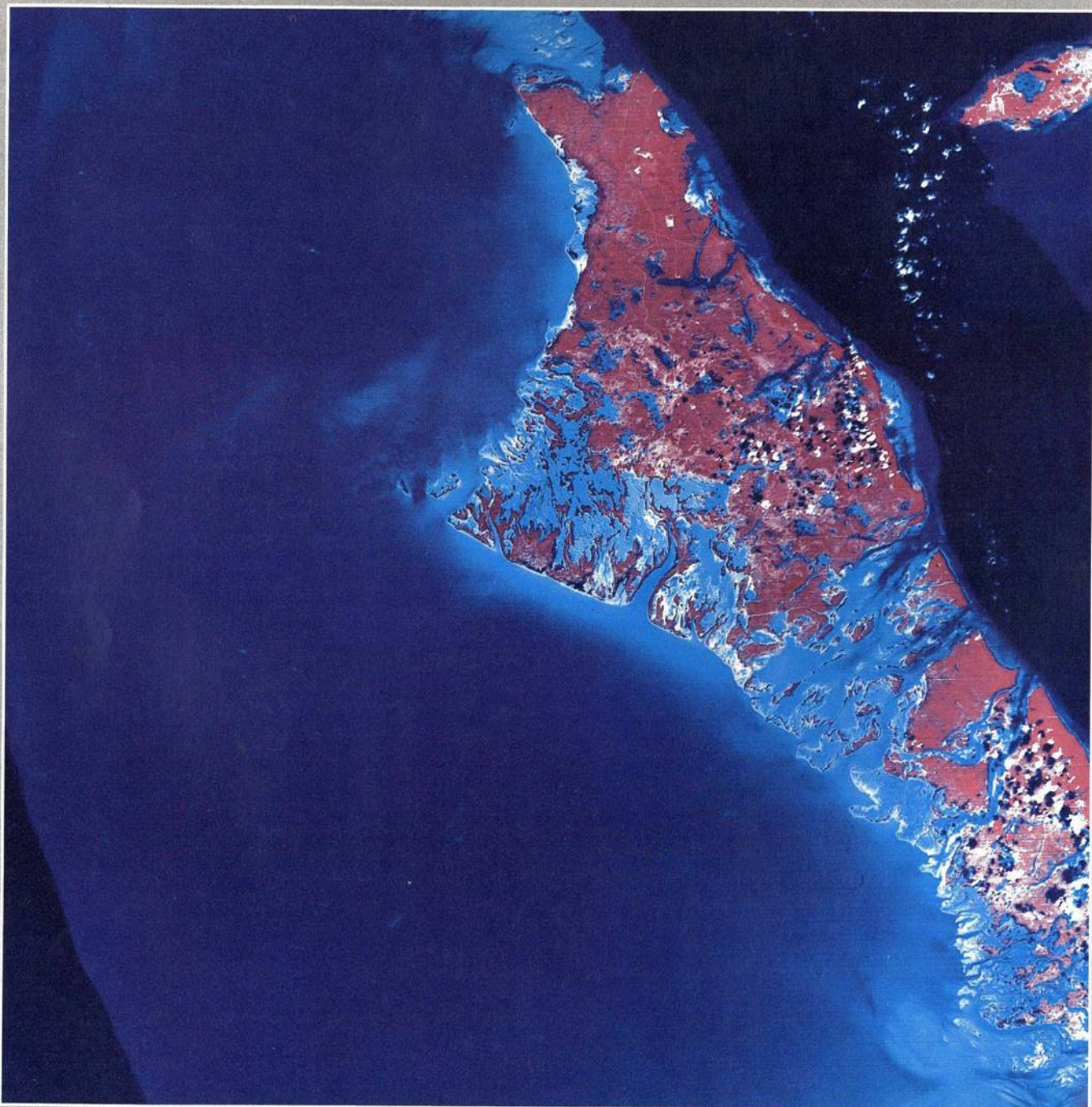


Left: Twisting along the left side of the photo are the eroded remnants of several hundred million year old sedimentary rocks in the Flinders Range north of Adelaide, Australia. The land is semi-desert. Below: Detroit (upper right) appears as a blue-grey patch on the bright red of vegetation in this false-color image. Light-blue streams of sediment are visible flowing into Lake Erie from the Detroit River and at Toledo (bottom center). NASA/Goddard photos.

by Andrew
Maslowski



Below: All sedimentary rocks begin as deposits of material. These then sink under the accumulating weight of later deposits and are converted by pressure and heat into rock. Andros Island in the Bahamas (shown here in false color) has a broad shelf of carbonate deposits to its west (left). In parts of the Bahamas, sediments have accumulated to a depth of over 4.5 kilometers — raw material for new mountain ranges in the distant future. NASA/Goddard photo.



As we begin to fly instruments past other solar system bodies — and land on them — the study of our own planet becomes more and more important for understanding what has happened elsewhere. Whenever planetologists evaluate craters on the Moon, Mercury, or Callisto, or study the rifted valleys on Mars, volcanos on Io, or the atmospheres of Venus or Titan, they always begin with their own frame of reference — the Earth. (See the accompanying portfolio of spacecraft images.)

* * * * *

Near the end of the 18th century, James Hutton, a Scottish medical man and farmer, formulated a geologic theory he called Uniformitarianism. In essence, Hutton stated that the same geological processes seen to be modifying the Earth's surface now had also been at work in the past. Thus, in his most famous phrase, the present is the key to the past.

This doctrine virtually created the modern science of geology, because it meant that the past was subject to the same rules that apply today — rules (or events) that anyone could investigate. It allowed scientists to study glaciation, sedimentation, weathering — all processes which take place in the present and which can be seen to have taken place before. However, some conditions that existed in the past do not exist today and so the present cannot always be taken *literally* as "the key to the past."

For example, 400 to 500 million years ago the Moon orbited much closer to the Earth than it does today. This generated immense tides — as much as 90 feet a day at many localities throughout the world. In addition, since the atmosphere then lacked a protective ozone layer, the Earth's surface received more intense radiation, hastening the rate of mutation among living organisms. Then, several millions of years later, great coal forests (which suggest a tropical climate) developed in locations where only a short time earlier — geologically speaking — deserts had existed.

Planetologists sometimes explain these

"abrupt" changes with plate tectonics — a theory that the crust of the Earth is made up of large masses (called plates) of granitic rock which float on a denser and more fluid layer of basaltic rocks. Sluggish currents in the basalt that are driven by heat welling up from the molten interior of the planet carry the plates constantly (though very slowly!) around on the surface of the Earth. Continental masses can collide and break apart; the present North American plate, for example, is believed to have been in contact with the European plate at least twice during the past 500 million years.

These plates can do a great deal: their motions alter latitude and longitude, and shift climatic conditions. The forces released when their edges rub together can stimulate mountain-building — or generate volcanic activity. And the motions can alter sedimentary processes which eventually will determine which types of rocks are deposited. The role of biology is also important: 300 million years ago erosion and flooding were probably more widespread than today — a result of there being fewer plants, especially grasses, to hinder erosion. (The earliest land plants evolved about 350 million years ago, while grasses and flowering plants have evolved in the past 50 million years.)

Because of this erosion, the atmosphere must have carried a lot of dust in it. This dust, both in itself and by acting as water- and ice-condensation nuclei, likely produced abundant cloudiness over much of the Earth. Our planet's albedo — its reflectivity — was greater, and as a result, less sunlight penetrated, which in turn created an environment for unique photochemical reactions.

According to fossil and lithographic records left in sedimentary rocks, other cyclic and episodic events have occurred in the Earth's past. Although lacking the regularity of the martian ice ages, terrestrial polar caps have also grown and shrunk in response to changes in the shape of Earth's orbit around the Sun. There is even evidence that this occurred in both hemispheres many times during the past 300 million years.

Floods, ocean-bottom-scouring turbidity cur-

rents, meteor impacts, and rapid land movements such as landslides are all examples of sudden geological events. Coupled with these are slower-paced events such as mountain building, faulting and folding of rock layers, and the rise and fall of sea level — events that may take thousands, even millions, of years to make their mark.

While Hutton's original dictum remains valid, the modern planetologist has learned to keep his mind open — processes that dominate one period of a planet's existence may be of little importance in the next. The "symphony of the Earth" has many movements, each scored with different tempos.

* * * * *

Shifting our attention outward, we find that Earth shares several fundamental geologic similarities with the other inner solar system bodies. These include such features as a rocky crust and stratification, meteor cratering, volcanism, crustal deformation, and surface weathering. Planetary scientists have come to think that most of the rocky material of the inner and outer planets and satellites is broadly similar, due to a common origin in the solar nebula. Elements such as iron, magnesium, silicon, potassium, and others abound throughout the system and are common ingredients of rocks on Earth — though the exact isotopic composition of the elements may differ.

Rock samples brought back from the Moon by six Apollo missions and the unmanned Russian Luna 16 probe show clearly that many Moon rocks, ranging from 3.0 to 4.6 billion years in age, have terrestrial equivalents. Some, however, differ in that they display higher iron concentrations, higher amounts of titanium, and lower amounts of water, as compared with terrestrial rocks.

Even before lunar landings provided first-hand evidence and absolute dates, planetologists, working from terrestrial analogues, had derived a relative lunar stratigraphic sequence from photographs. Amazingly, the sequence held up in all important respects after the landings. The vindication of "photo-stratigraphy" has meant that

scientists can analyze at least part of the geology of another world without ever banging a hammer against the rocks of the planet itself. In a broader sense, too, knowing which came first — a volcanic deposit or a meteor impact — can help give scientists a better understanding of the entire sequence of events that transformed a given part of the amorphous solar nebula into the complex planet or satellite we see today.

So far as we know, meteor bombardment has been the chief sculptor of the surfaces on Mercury, Venus, and Mars, and on the moons of Earth, Mars, Jupiter, and Saturn. Except in the case of Earth, craters often form the most prominent topographic feature of these worlds and have provided planetologists with vital information concerning surface geology and relative aging.

The exception — Earth — is outstandingly different. Since a layer of water hides over 75% of its surface and with its geologically active crust exposed to vigorous erosion under a relatively dense atmosphere, only fragmentary traces of Earth's ancient cratering history are visible. But scientists are grateful for what they have, since terrestrial craters — though mostly in ruins — are the only ones they can examine directly. Many unanswered questions still linger: What do meteor bombardment rates tell us about the population of objects in the inner and outer regions of the early solar system? Are there radial effects grading outward from the Sun — and are they significant? Have all bodies undergone similar episodes of bombardment?

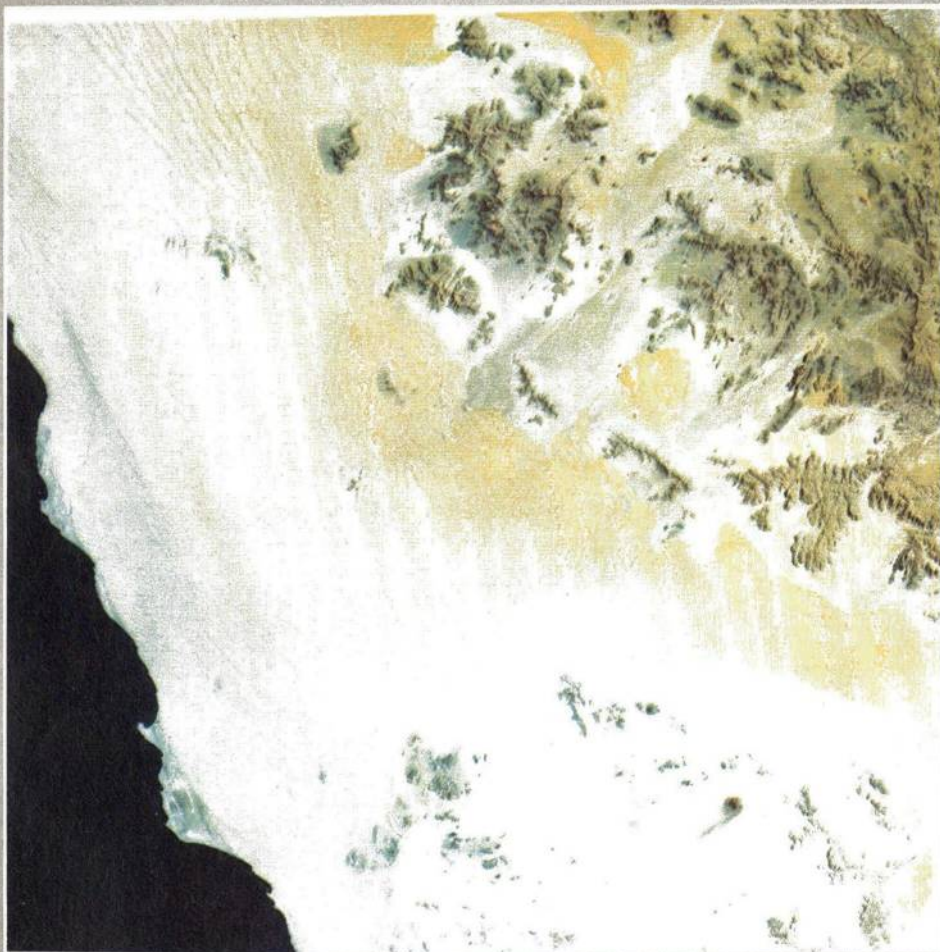
Quiescent and explosive volcanic eruptions are believed to have occurred on a large percentage of the planets and satellites in the Sun's system. Although evidence of volcanism may have been destroyed by meteor impacts on some worlds (such as Mercury and the Moon), on other worlds — Io, for instance — the evidence is irrefutable.

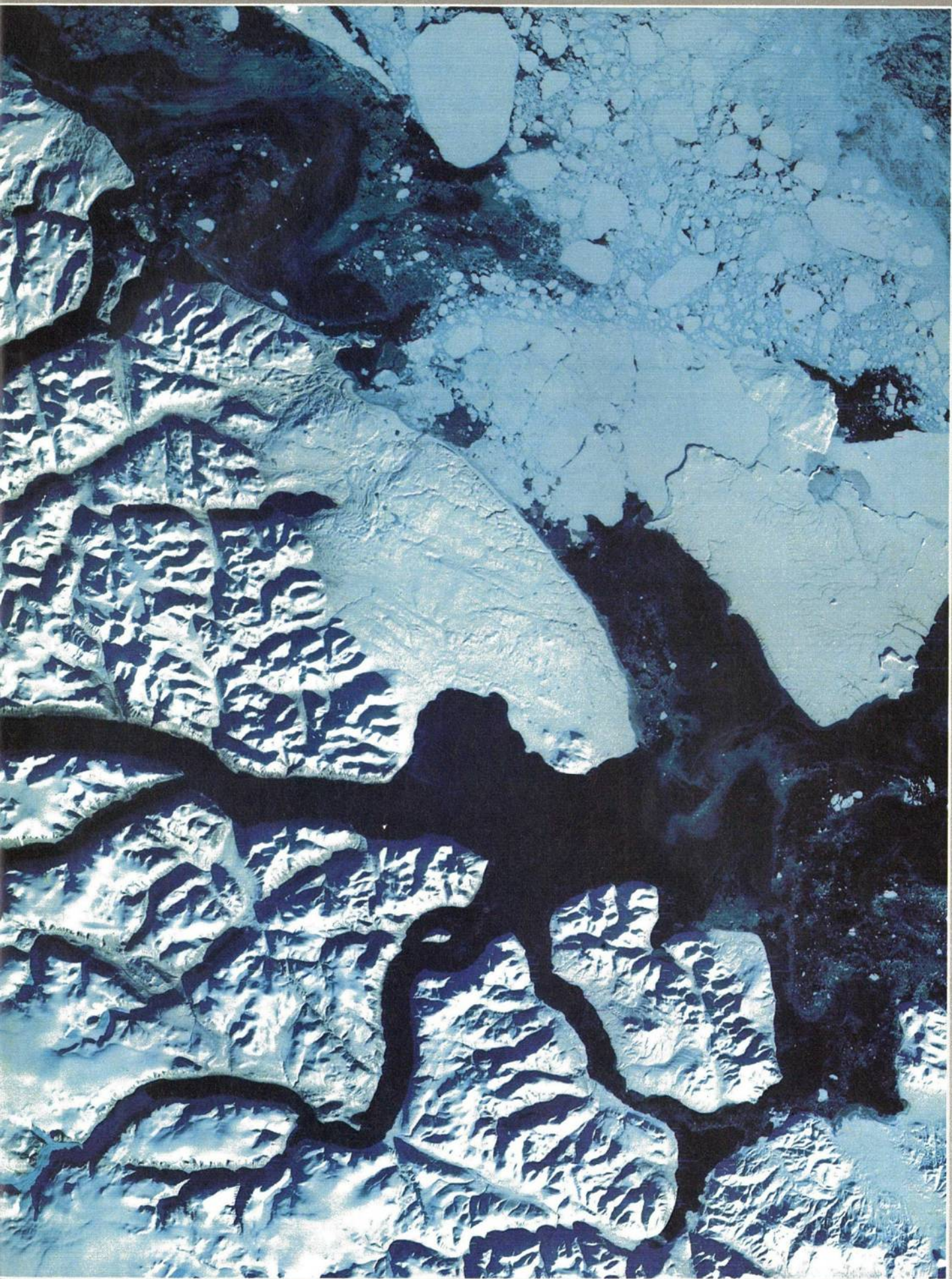
Jupiter's sulfur-encrusted satellite excited scientists around the world when Voyager I sent back its spectacular images that showed active volcanos. At least nine different sites were counted during the two Voyager flybys in 1979, making Io

Below: Water is the dominant sculpting agent in all terrestrial landscapes. The Mississippi River (here flowing past Memphis, Tennessee) has cut new channels for itself many times. The old water-courses show as "ox-bow" lakes and curves in the pattern of cultivated fields. Planetary scientists can use such features to deduce a "paleo-topography" and gain insights into past geological events. NASA/Goddard photo.



Right: Mountains on the northern coast of Greenland are heavily dissected by glaciers that flow off the Inland Icecap down the branching valleys to meet the sea. Icebergs from the glaciers transport boulders, pebbles, and a fine rock "flour" out onto the ocean; the bergs then melt and deposit the litter on the sea bottom. Below: In a similar fashion, the coastal mountains of Namibia are being transported seaward — though the agent here is liquid water. But since the region is very dry, rains are infrequent and winds have time to heap the detritus into dunes. NASA/Goddard photos.





Below: The most prominent feature in this image is the 5,000-foot-deep valley carved by the Colorado River into the sedimentary rocks of northern Arizona: the Grand Canyon. The tributary canyon in the center of the photo is the Little Colorado. A dusting of snow appears as whitish patches in the upper left and elsewhere. Right: When a river laden heavily with sediment — such as the Mississippi — flows out into the ocean, the sediment settles out, creating a delta that bulds steadily seaward. EROS Data Center photos.

the most volcanically active body in the solar system at that time. Although at least seven different volcanos erupted on Earth in 1981, they did not all erupt at the same time, as with Io, and in proportion, the activity on Io was far greater.

It turns out that planet Earth is far from the only solar system body to have an active crust. Fracturing, folding, or faulting has occurred on many worlds, including Mercury, the Moon, Mars, Jupiter's Europa, and Saturn's Enceladus. Moonquakes and marsquakes attest to one potential cause for this fracturing and faulting — internal disturbances powered by residual internal heat. The freshly-worked surfaces on Jupiter and Saturn's iceball moons exhibit another cause — tidal stress. Volcanism and cratering also contribute to other

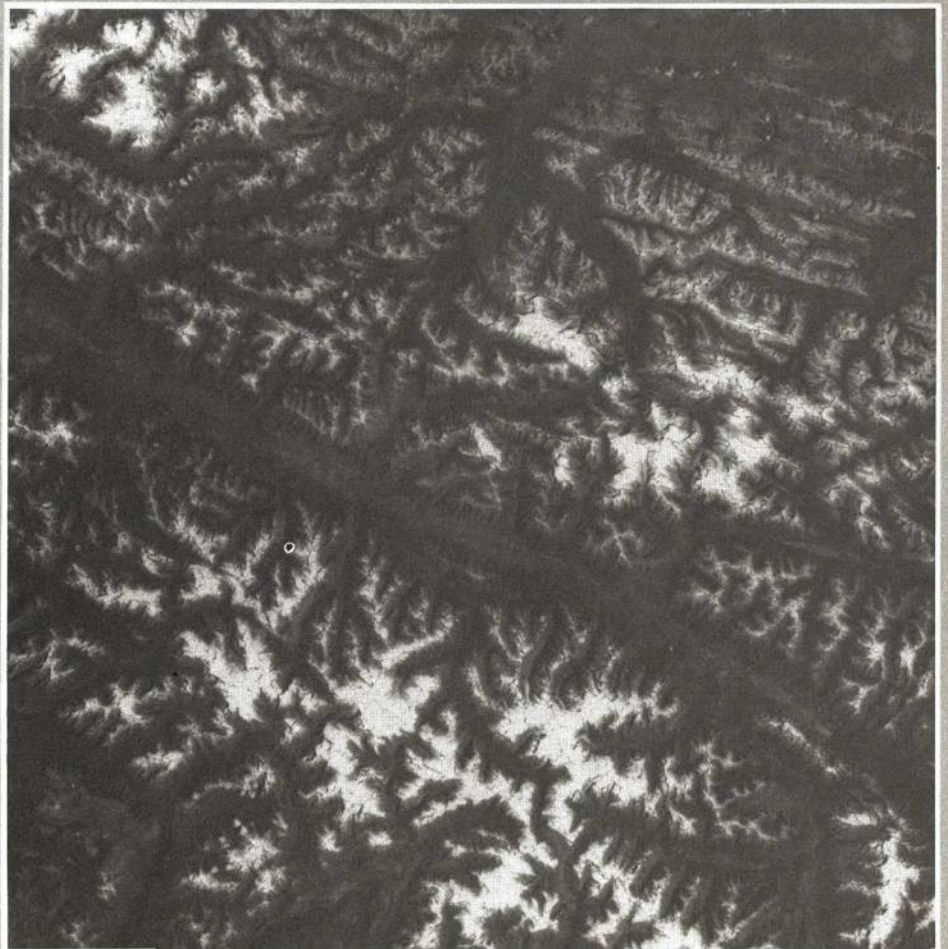


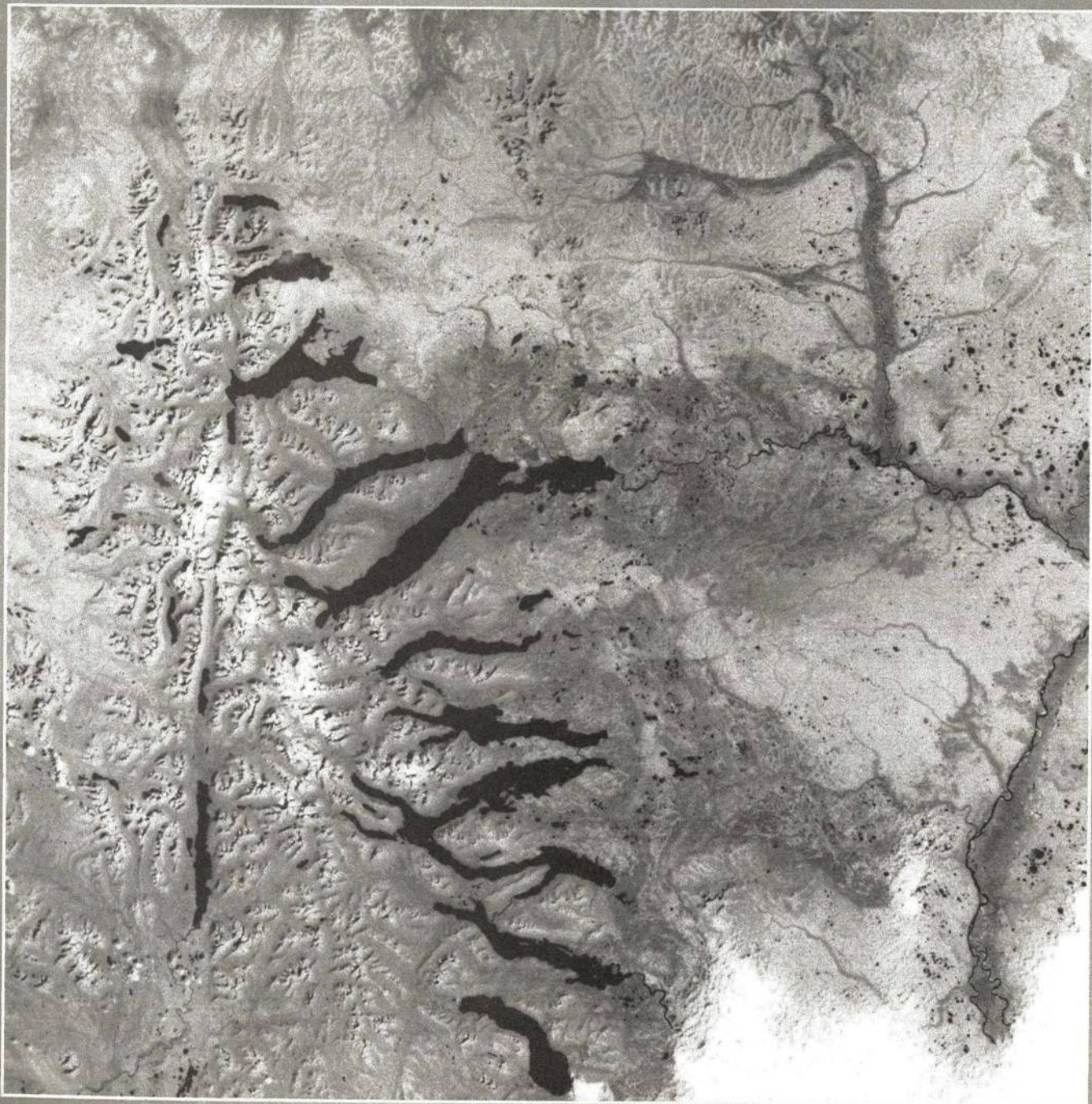






Left: Even when rocks vary only slightly in their resistance to erosion, substantial landforms can develop. Here we see folded sedimentary rocks in Namibia that are eroding in a very dry environment. Below the hogback ridges lie sheets of waste sand and gravel. **Below:** Compare how much more rapidly erosion works in a region of higher uplift and heavier precipitation — the Rockies in British Columbia and Alberta. The deep channel running diagonally across the center is the Fraser River Valley. NASA/Goddard photos.





forms of surface deformation.

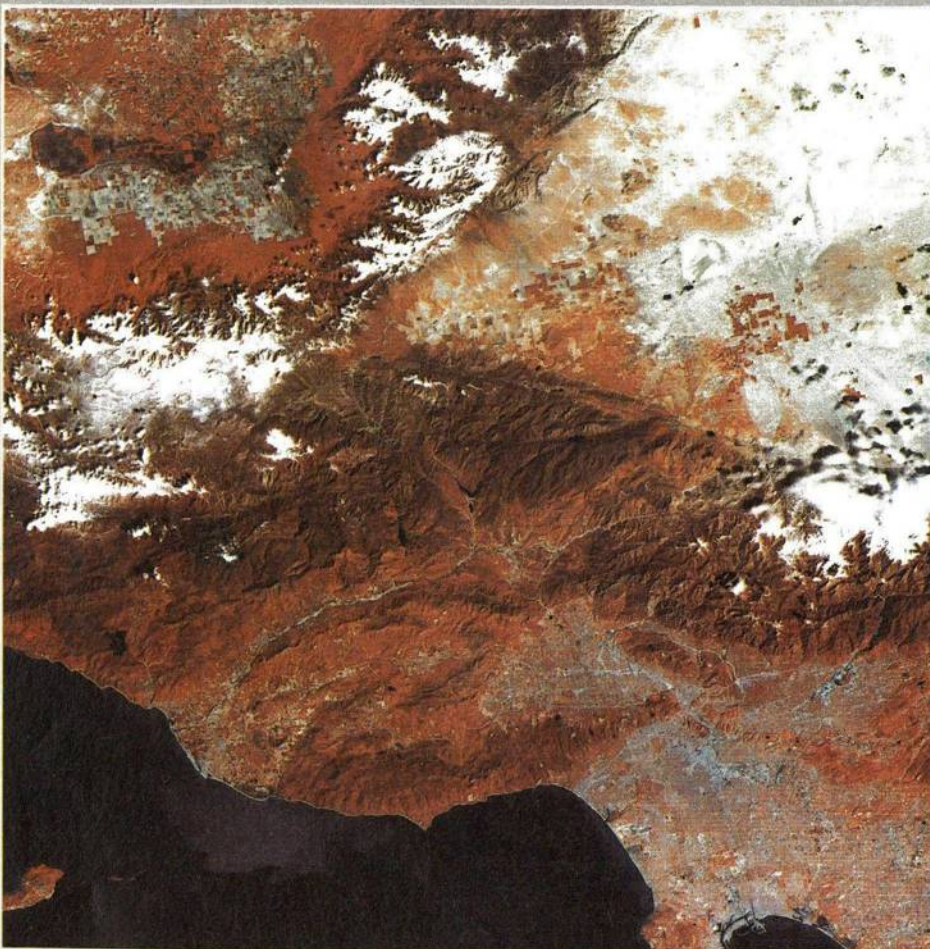
Mechanical and chemical weathering — the dominant geomorphic processes on Earth (amply shown in the accompanying images) — are also known to exist on Venus and Mars, and are thought to occur in some form on most of the other objects in the solar system. Extremes of temperatures, gravity, the action of winds, and other factors all aid in the breakdown and transport of surface materials. Even primitive "soils," or dust layers, can be moved around by winds, especially on Mars.

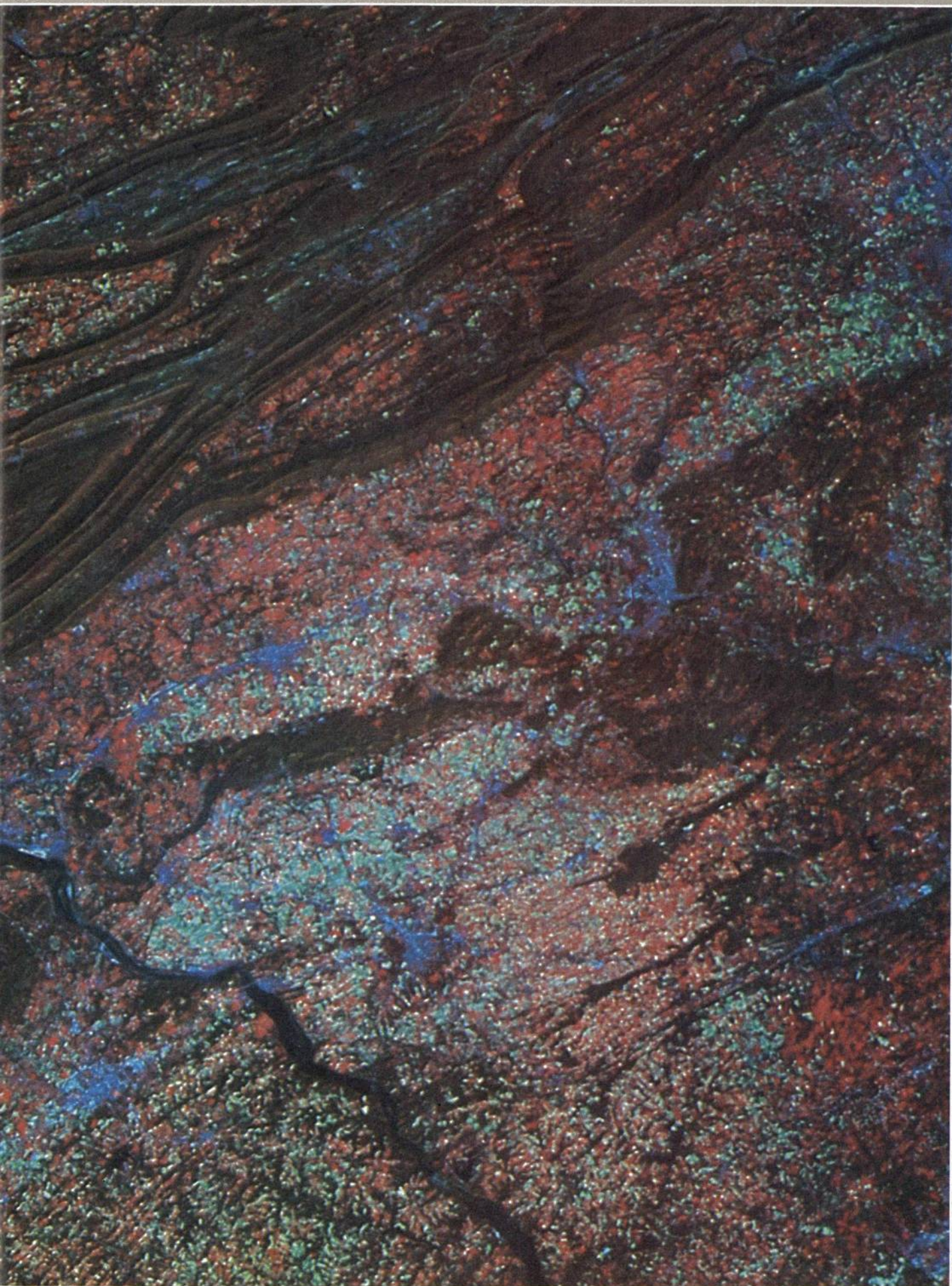
Water and/or ice — both of supreme terrestrial importance — are possible candidates for eroding the surfaces on some planetary bodies. In the most famous example known, these fluids eroded braided stream beds on Mars. No one has yet found glacial

Left: These elongated Alaskan lakes are similar to those in northern New York state and have an identical origin. They fill valleys that were gouged out by glaciers. **Below:** The eruption of Tiatia volcano in the Kuril Islands sends a plume of ash and smoke downwind (lower right) and creates a shock-like front in the cloud deck near the volcano. NASA/Goddard photos.



Right: One of the most interesting features of the folded Appalachian chain is how in some places the drainage pattern of a river cuts across the ridges. This happens when mountains that have been buried are exhumed by a river, which chops through the emerging ridges as it uncovers them. EROS Data Center photo. Below: Los Angeles (lower right) and the tangle of mountains and faults to the north and west of it. NASA/Goddard photo.





Below: The curious structures in the center of the photo are U-shaped blocks raised above the surrounding flat terrain — a reversal of the usual way topography develops. The region lies to the east of Cape Beaufort, Alaska, and the streams in the area flow mostly across the geologic structures (compare with the photo on the previous page). NASA/Goddard photo.

moraines on Mars resulting from its ice-caps, but the polar regions there have a curious type of layered terrain, generated by the unusual freeze-and-thaw conditions.

In essence, the modern union of geology and astronomy — planetology — proceeds to weave a single coherent story out of the dozens of individual examples that make up the Sun's retinue of solid bodies. Though the work remaining to be done is immense, the critical first steps have been taken. Never more will it be possible to examine any planet or moon in splendid isolation from its neighbors — the kinship of all has been recognized. And by studying terrestrial geologic processes, planetary scientists are forging keys to unlock the mysteries of worlds other than ours.



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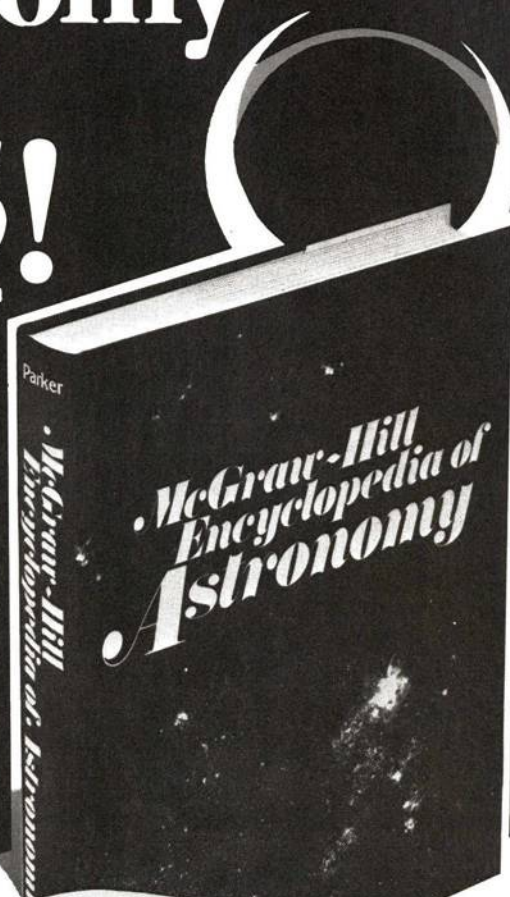
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The Tragedy of the American Space Program

When Apollo 11 landed on the Moon in July of 1969, it seemed as if the exploration of the Moon had begun in earnest. At great expense the United States had set up facilities, organized thousands of skilled technicians, and designed the most powerful machine ever made — the Saturn V rocket — so that Americans might reach the Moon. Detailed plans were drawn up for nine more Moon landings to follow in the footsteps of the first. Rockets for those flights and others had already been built or were nearing completion, and only a relatively small additional expenditure was needed to use them.

But after a total of only six landings, and with a great deal yet to be learned, the United States abandoned the Moon. Today, Saturn V rockets meant to carry Americans to the Moon are lying on their side on the ground, while European and Japanese tourists pose for pictures before them. Lunar modules built for flight rest on imitation moondust in museums.

These Saturn Vs and lunar modules make a profound statement about our nation and about our character as a people. There is at least a deep irony here, and perhaps it can be called a tragedy. It is the tragedy of a people whose practical genius enables them to build machines for exploring the universe, but whose practicality prevents them from finding the motivation to do so.

The American space program is a tragedy not only in the sense of being a misfortune, but also in the original sense that it is a tale of a great person brought down by a flaw of character. Often, particularly in Shakespeare, the very trait that makes a person great turns out, in the circumstances in which he is placed, to be limiting or fatal. And as the tragic hero moves

toward his fate, he may not even realize that his character has begun to work against him. This can occur in evolution, when a species adapts too well to a particular way of life and then is incapable of change when its environment changes — the traits that made the species successful now bring on its downfall. And this also occurs in human history, when the traits that make a nation great in one age may prevent it from being great in another.

The largest factor in the shaping of the American character has been the challenge and opportunity of settling a vast continent. The first settlers on the Atlantic coast faced the necessity of surviving in a wilderness that offered none of the comforts of European civilization. There were no shops, merchants, farms, villages, or roads, and certainly no universities, museums, or concert halls. There were only immense forests. To survive, the settlers had their own hands and whatever tools and supplies they brought with them. Under these conditions the only valuable skills were those that contributed to survival, that helped turn forests into farms and villages. Men were respected for their practical abilities, and since cultural and intellectual pursuits contributed little or nothing to taming the wilderness, they were little respected and often held in contempt.

If the wilderness forced Americans to have practical values, it reinforced these values with a promise: While it might demand a lot of its inhabitants, the wilderness also yielded up in the same full measure. Americans saw the continent as a treasure chest of land and resources far more abundant than they could ever have acquired in Europe. There, the abundant life belonged to the upper classes and common laborers had little chance of

acquiring it. But in America abundance seemed to be available to everyone, and those who worked harder got more of it. For 250 years, as the frontier moved westward, the pressure of survival and the promise of abundance shaped American values indelibly.

The practicality of the American mind gave Americans a special talent for practical invention. From the first, Yankee ingenuity produced one clever device after another. The land encouraged this inventiveness by rewarding those who found ways to make work easier and more efficient. But inventiveness did not merely give Americans greater abundance, it created wholly new kinds of abundance based on industry, which opened a new phase in the formation of the American character. The earliest immigrants arrived in America almost empty-handed and had to fight for survival. But by the late 19th century the wilderness was gone, and the newly arrived poor had to wage their battle for survival in cities and factories. This also compelled people to value practicality, and reinforcing these values was not only the promise of abundance for those who worked hard, but quick and vast wealth for those who could invent something useful to an industrial society. Inventors such as Edison became national heroes not only because they offered an example of what anyone could achieve, but also because they were seen as public benefactors.

Inventiveness rapidly became an important part of the national identity. Americans had long had an acute cultural inferiority complex in relation to Europe, but technology was clearly something at which Americans were superior. With much justification, Americans thought of themselves as leading the world into a heroic technological age. The pride of Americans in their democracy was deeply connected to the pride they

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took in their technology — was not the abundant good life they were building ample proof of what humans could achieve if they were free?

But the relentless emphasis on practicality and financial success made America a rather uncomfortable place for artists and writers. Cultural and intellectual pursuits, as judged by utilitarian values, were held to be useless, silly, or unmanly. Frustration with this attitude drove several generations of American writers and artists to exile themselves in Europe. The American preoccupation with success, technology, and growth became one of their main themes — with his novel *Babbitt*, Sinclair Lewis coined an epithet still in use today. Writers not only condemned those values bitterly, but hastened to the other extreme and adopted an anti-technological romanticism.

These two currents in American life — a strong emphasis on practicality and an equally strong reaction by intellectuals against it — have combined to undermine the American space program since its inception.

For nearly a century, Americans had a firm and secure belief in their own technological preeminence. But after World War II, Americans were surprised to find another major power, the Soviet Union, claiming that they and not the Americans owned the future. Americans were exasperated by Soviet portrayals of American society that bore little resemblance to their highly positive self-image, and were threatened by the Soviet insistence that their very different society would soon surpass the United States.

Americans remained confident, however, for it seemed that the Soviets were far behind — until October 4, 1957. On that day the Soviets launched a small satellite into Earth orbit, and Americans reacted with something approaching hysteria. President Eisenhower tried to reassure the country that as far as military implications were concerned, Sputnik was no big deal. But Eisenhower missed the point. Sputnik came as a deep shock to Americans because they had come to measure the worth of their nation by one thing — technology — and this dramatic Soviet triumph compelled Americans to question their technological abilities and, by extension, their entire way of life.

It should have been an exhilarating moment for the entire human race. For ages humans had wondered about the universe beyond Earth, but it seemed we would never leave our own planet. Now the door to space lay open, and many bold dreams had become possibilities. Humans were free to explore the cosmic neighborhood; the

mysterious planets could be revealed. After four billion years of evolution, life was able to leave the planet of its birth.

But Americans didn't see it that way. They saw Sputnik only in the context of the Cold War, as a sign that the United States was losing. This seemed to be confirmed by further Soviet space triumphs, especially the first human space flight. Meanwhile, American space efforts resulted in several spectacular launch pad explosions. Even when the flights were successful, they didn't match the grandstand appeal of the Soviet successes.

It was in this context that President Kennedy announced in 1961 the goal of landing a man on the Moon. Americans would go to the Moon not to explore it but to prove that they could create the technology to take them to the Moon — and thereby restore their damaged sense of national preeminence.

As you might expect, when Americans put their practical talents to work in a big way, they soon surpassed the Soviets. In fact, the

To the intellectuals, the Moon landings seemed like the triumph of all the values they detested in American society.

Soviets owed most of their initial lead to larger rockets — an outgrowth of their inferior bomb-building technology — and once this advantage was gone, they couldn't come close to the sophistication of American spacecraft. But the Soviets concealed this fact throughout most of the 1960s while the Americans forged steadily on. Finally, American know-how won out and Apollo 11 landed on the Moon in July 1969. Americans celebrated for a moment and then popular support for the Apollo program collapsed.

And why not? Once Americans had proven their technology was better, there was little to motivate more moonflights. Americans had done what they set out to do — beat the Soviets to the Moon — and with that accomplished, there was little practical reason to keep on going there. The Moon held only dust and rocks, and what use were they? The practicality that made Apollo possible now turned against it with a vengeance. People ridiculed NASA for spending so much money to collect a few boxes of rocks. Television stations were showered with complaints when they interrupted golf matches to show Moon-walks.

American practical values simply would not support the exploration of the Moon. Americans were quite willing to support practical aspects of the space program, such as Earth resources and communications satellites — but exploration for the sake of knowledge was something else.

The intellectuals offered little or no support either. In fact, because Apollo had been conceived as a technological exhibition, they were largely hostile to it, often bitterly so. To the intellectuals, more isolated and powerless than ever before, the Moon landings seemed like the ultimate triumph of all the values they detested in American society.

With no support, and with an expensive war in Vietnam and troubling problems at home, the United States abandoned Apollo. Practical ingenuity had given Americans the ability to explore the entire solar system. The facilities, personnel, and technical sophistication were all there, but the necessary values weren't — and this prevented Americans from pursuing one of the most extraordinary opportunities ever offered a nation. Americans not only canceled the Apollo program, they abandoned plans for research stations on the Moon and a manned expedition to Mars. Again and again, ambitious ideas for unmanned exploration were scaled down, until a decade later there was almost nothing left. In 1981 Americans passed up a once-in-a-century chance to explore Halley's Comet and they canceled probes to Venus and the Sun. The White House even tried to turn off Voyager 2, which had explored Jupiter and Saturn and was already on its way to humankind's first look at Uranus and Neptune. All that remained was the Galileo probe to Jupiter, and even that was nearly canceled by Congress in 1978 and by the White House in 1981.

Advocates of space exploration watched in frustration as the exploratory programs were gutted, but few understood why. Most space advocates shared the same values as the rest of American society and weren't prepared to understand or question them. In fact, they usually tried to justify space exploration in terms of those values, as if no other rationale were possible or meaningful.

At first, advocates pointed to the technologies developed for exploring space that have been put to work in everyday life — technologies from computers to medical equipment to Teflon frying pans. Or they pointed out that NASA spending stimulated the economy. These arguments were actually rather flimsy, since many if not most of these technologies could have been developed apart from space exploration, and far more cheaply.

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Moreover, the money pumped into the economy by space exploration could have been pumped in by other means. But Americans seemed to gravitate automatically towards this argument, and apparently didn't see anything odd about justifying the highest needs of the human mind in terms of the lowest needs of the human body. It was like buying a literary masterpiece because it happened to make a good doorstep, or going to a museum because it provided employment for guards and janitors.

Space advocates also suggested that studying the geology or weather of other worlds might teach us something of practical value about the geology or weather of our world. This may well have been true, but it was sad that Americans couldn't explore space for its own sake, instead of trying to demonstrate how it might improve life on Earth.

Next, the advocates invoked the positive images of exploration that Americans have acquired from their history. They intoned the name of Columbus, suggesting that our spaceflights were like the European explorations of America and asked people to imagine the consequences if Columbus had been prevented from exploring. They pointed out that Americans had become great by pushing back frontiers and that space was the new frontier.

But this argument missed the mark also. The European explorations of America and American pioneering of the wilderness were done in pursuit of wealth — wealth the explorers could take immediate, personal possession of. Exploration was much less compelling when it was done for the sake of knowledge. Spacecraft sent to Saturn or Mercury returned only photographs. And the Columbus analogy was false, too. When Columbus reached America, it only meant that Europeans had finally gotten around to noticing a part of the Earth that Asian aboriginal peoples had discovered and settled thousands of years before.

Finally, space advocates appealed to national pride. They suggested that space exploration would impress the rest of the world and make us proud of belonging to the nation that discovered such wonders. But hardly anyone mentioned what we should feel about belonging to a universe that contained such wonders. Space exploration is the enemy of all provincialisms and lets us see that we are part of an extraordinary universe. But Americans, it seems, get excited about the universe only when the universe gets them excited about their country.

There were a few who tried to justify

space exploration without appealing to traditional American values. But these people were often very unprepared to do so — adrift in an ill-charted sea of values, they floundered about, uttering banalities ("Because it's there") or calling upon biological imperatives, such as salmon having to swim upriver.

One justification alone should have been sufficient — knowledge. We humans are born into a vast and intricate universe that has been going on for billions of years and will go on for billions of years more. The universe might have passed from beginning to end without anyone ever seeing it or knowing that it ever existed. We are given a chance to know this universe, to see all that has happened, and all that will happen. We awake one day in this strange place, and we have only a moment in which to find out what it's all about. Each of us has a choice: Will we pass through the universe as a stranger, oblivious to all its wonders, or will we try to experience it as fully as we can?

Exploring the solar system is an important part of experiencing the

Americans seem to get excited about the universe only when the universe gets them excited about their country.

universe. It allows us to see what has happened in our cosmic neighborhood for the past five billion years, and what probably goes on in other solar systems. And we explore the solar system not only to know the universe, but also to know ourselves. Our lives are part of the universe, the result of 15 billion years of cosmic evolution, and cannot be understood apart from it. We explore not to make our lives more comfortable but to make them more meaningful.

Will Americans be able to accept knowledge as a sufficient reason for space exploration? Americans do seem to be developing more mature values, but since we still tend to cherish things largely according to their usefulness, the American exploratory space program will probably languish.

There is, however, one thing that could reignite space exploration. The Apollo missions revealed that the Moon is rich in metals needed by industry. Asteroids, moons, and other planets seem to hold similar resources. Gerard O'Neill and others have developed detailed plans for obtaining and utilizing these resources, which would not only solve the problem of

diminishing resources on Earth, but open up staggering new possibilities of abundance. Like most bold new ideas, the possibility of exploiting the resources of space will take a while to sink into the public mind. If Americans continue to think of this as something impossibly remote, then they will probably not support space exploration. But if Americans can be convinced that this is an immediate, practical, and economic possibility, it may provide just the motivation they need. Some advocates of space exploration have recognized that this is a truly compelling practical reason for exploring space, and have seized hold of it as the best way of appealing to traditional American values.

But if space turns out to offer little scope for exploitation, Americans may well leave exploration to the Soviets and Europeans. Soviet ideology places higher value on the pursuit of pure knowledge than does the unwritten American ideology of practicality. Europeans are much more comfortable than Americans with justifying actions by the needs of the mind, and European intellectuals may be less alienated from science and technology than their American counterparts.

Two books on the Moon program offer a curious sort of proof of this. One book, *Of a Fire on the Moon*, was written by an American intellectual, Norman Mailer, and the other, *If the Sun Dies*, by a European intellectual, Oriana Fallaci. Despite an engineering background in college, Mailer is very distrustful of the space program and speculates that it may be the work of the Devil. Fallaci, too, is disturbed by American values and especially by one technician she met who advocated obliterating the museums, churches, and literature of Europe because they weren't practical. But in the end she affirms space exploration on the grounds of knowledge.

Practicality has created America's greatness, but we have paid a dear price for it — and in the space age, that price is paralysis. While other nations are gradually catching up to American technology, Americans do not seem to be doing as well in the field of values. When Halley's Comet flies past the Earth in a few years, it will be studied by two Soviet spacecraft, a European spacecraft, and a Japanese spacecraft. The United States could have launched a spacecraft far more sophisticated than any of these — one that would have revealed much more about the comet. But that spacecraft won't be joining the Saturn Vs and the lunar modules in our museums. It was never even built.

Don Lago
Columbia, MO

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SUBJECT

M42 THE ORION NEBULA.

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M8 The Lagoon Nebula

NGC 6523

Diffuse nebula in Sagittarius

RA 18h 02m

Dec -24° 23'

Mag 6.0



On a clear, moonless summer night, if one looks at a point in the southern sky about 6 degrees north of the star γ Sagittarii, one may detect even with the unaided eye the dim, undecorated glow of the Lagoon Nebula. A small telescope reveals much of this magnificent object's splendor: its sparkling star cluster (NGC 6530), its pale billows of nebulosity and the dark end of the obscuring dust lane across its center.

M8, one of the greatest of the 11 II (ionized hydrogen) regions in our galactic neighborhood, is a complex object. The star cluster appears to lie at a distance of about 1000 light years behind it. The very compact, black 'globules' that lie in the foreground, silhouetted against the glow of the II II region, are believed to be cosmic material for advanced in the gravitational collapse that gives birth to new stars. NGC 6530 itself is believed to be a cluster of some of the youngest stars known, probably no more than two million years old. They were, themselves, dark globules that had not yet become luminous.

The two brightest red stars, prominent in the telescopic view of M8, are θ Sagittarii and Herschel 36. These are not relatively nearby foreground objects, but bright, energetic stars associated with the nebula itself; they have been identified as the principal sources of ionization of the surrounding nebulosity.

The Lagoon's distance is a matter of some uncertainty. The Royal Astronomical Society of Canada's *Observer's Handbook* cites a distance of 4500 light-years. Burdman's *Celestial Handbook* accepts the evidence for a much remoter position, about 3200 light years away from our solar vicinity. If the latter estimate is used, the Lagoon is an enormous interstellar cloud, about 100 light-years wide. On this scale, the full diameter of our solar system is one hundredth that of the smallest dark globules observed in the Lagoon.

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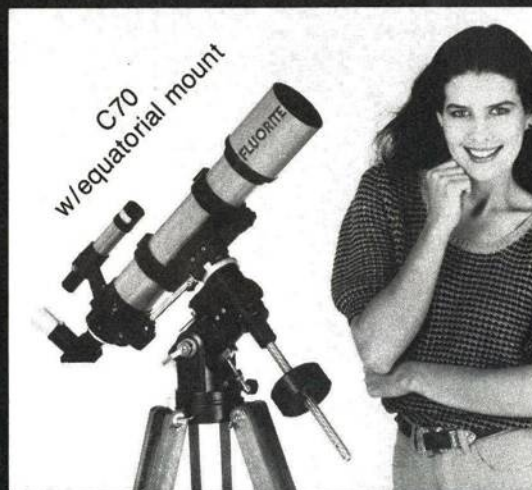
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ASTRONOMY IN FOCUS

Magnitude vs. Surface Brightness

Sir / I recently purchased a telescope and have a particular fondness for observing galaxies. In the past year you've run three very interesting articles on this subject ("Searching for Supernovae" in April 1982, "Observing Edge-On Galaxies" in May 1982, and "Get Ready for the Virgo Cluster" in March 1983).

The articles were great, but there seems to be an inconsistency in the magnitudes of many of the galaxies listed in these articles. In my telescope some of them listed as brighter than others looked fainter. Keep the articles on galaxies coming!

Steve P. Spear
Dresher, PA

Mr. Spear / Our magnitude data were correct, but another factor comes into play that explains the variable visibility of galaxies. Integrated (total) magnitudes for galaxies — the standard magnitudes — represent the brightness of nebulous objects if they were compressed into a stellar point. But they are actually large, spread-out objects. So a more important consideration in observing galaxies (or any nebulous object) is surface brightness, the measure of the brightness of a given area of object. Imagine cutting all the galaxies up into little squares 1' across. A tenth-magnitude galaxy measuring 1' across could appear as bright as a seventh-magnitude galaxy spanning 10'; although the total light for the seventh-magnitude object is greater, it is more spread out, and each little area of nebosity appears fainter than magnitude seven.

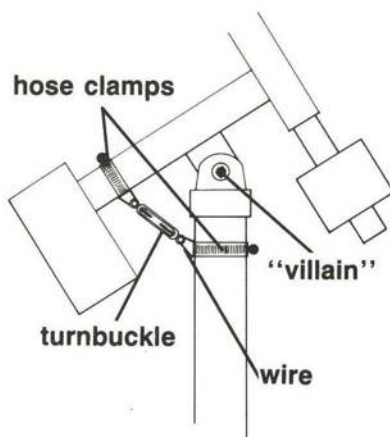
Adjusting a Polar Axis Smoothly

Sir / I thought that ASTRONOMY's readers might be interested in a little gimmick I made, which is a great help in getting the polar axis on a German

equatorial aligned.

Characteristic of most German equatorials is a bolt-and-nut that holds the polar axis at the correct angle for one's latitude (see "villain" below). The problem with these things is that if you loosen the nut sufficiently to allow adjustment, you run a very real risk of having the whole business slip abruptly, perhaps mashing some fingers in the process.

After horsing around for a while with this particularly evil bit of technology, I came up with my (ahem!) Precision Polar Alignment Device. See sketch:



The PPAD consists of two hose clamps, one small turnbuckle, and some picture wire. Make the loops of picture wire fairly stout, so they'll remain stiff. When it is in place, you can safely loosen "the villain" and make small, accurate, and easy changes in the polar elevation to get it right — and then re-tighten the bolt to lock the whole thing in place.

Nick Henderson
No. Wilkesboro, NC

Distant Subscriber

Sir / I discovered ASTRONOMY last year. While visiting a friend in West Belmar, New Jersey, I happened to see the June '82 issue on a newsstand. Of course, right away I was hooked.

Anyhow, I'm now writing to you and AstroMedia to say a big thank you. I had previously informed you that my January issue of ASTRONOMY had not arrived. Well, to my delight, the replacement copy you sent arrived in good order on the first of this month (June), and I can only say how glad I am that I did not miss this issue. Like all the other issues I have had, it is truly superb.

I suspect the reason the January issue did not arrive was that the address label on the wrapper had been torn off. The June issue, for example, arrived with its label hanging by a thread.

By the way, I received your notice that my subscription has expired as of August '83. I can assure you that you will have received my renewal by the time this letter reaches you, as I posted it at the beginning of June. Unfortunately, we are not allowed to send for more than one year at a time owing to the scarcity of foreign currency — otherwise I would take out a three year sub.

I've been doing practical astronomy since 1961. I built a 11'6" brick sliding-roof observatory (I am a bricklayer by profession) to house my tandem German-mounted 10.3 cm f/13 and 7.6 cm f/18.5 refractors. I joined the BAA in 1963 and the ASSA in 1967. I currently belong to the comet and nova search sections of the ASSA.

Our local group, the Bulawayo Astronomical Society, meets once a month. We hold regular star parties and ordinary meetings. Our latitude (20°10' south) and altitude (1,330 meters) make this country ideal for astronomical work, and yet we have no national observatory — a great pity.

I own two SLR cameras and do my own processing and b&w printing — but the near total non-availability of film here does get a bit frustrating, especially when I read all about the gear available to the amateurs in your country. Still, I suppose we should count our blessings!

All best wishes and once again, thanks so much.

Jack McBain
Bulawayo, Zimbabwe

North Americas Aplenty!

Sir / There certainly were a lot of photographs of the North America Nebula in the June *ASTRONOMY*. Whenever I see pictures of this object, my attention is always drawn to two open star clusters that seem to reside within the nebula.

The two clusters show best in the photo on page 12 by Rev. Royer, but can be picked out in nearly every version in the issue. The brighter cluster, situated at about "Ohio" in the continental outline formed by the nebula, is NGC-6996. The sparser grouping of stars near the "Oregon coast" is catalogued as Collinder 428.

Both objects are easy to view with a 6-inch or 10-inch telescope, and even a 2.4-inch refractor shows about ten stars in NGC-6996.

Gosta Lynga's *Open Cluster Catalogue* rather surprisingly gives distances for both clusters as about 500 parsecs. There is no published photometric study of either cluster, so perhaps the distance is based on an assumed association with the nebula — but as the text on page 12 shows, this distance is by no means certain.

Brian Skiff
Flagstaff, AZ

What Comet Was That?

Sir / As a professional historian and sometime astronomy buff (but constant reader of *ASTRONOMY*), I am writing for help. While reading Elijah Avey's *The Capture and Execution of John Brown*, I found the following:

"Forbodings of the coming storm were in the air, in everyone's heart and minds and mouths. Every natural phenomena was clothed with peculiar significance. The great comet that flamed across the heavens was taken as a sign of approaching war. Strange celestial lights, which nightly illuminated the heavens for weeks with a lurid glow, the like of which had never been seen by the people, filled their minds with morbid dread."

Avey's book was first published in 1906 and reprinted by Afro-Am Press in 1969. As an eyewitness to the hanging of John Brown at Charleston, Virginia (now West Virginia), in

December 1859 on the eve of the American Civil War, Avey was describing northern Virginia during the interval between Brown's raid on the federal arsenal at Harper's Ferry, part of his abortive attempt to end slavery in the United States, and his execution for treason.

Can anyone tell me what comet "flamed across the heavens" at the close of 1859?

Paul D. Casdorph
West Virginia State College
Institute, WV

Unity in Space

Sir / I applaud the letter from John M. Port of Glasgow, Scotland that appeared in your July '83 *In Focus*.

My interest in astronomy and the space programs stems from the view that these activities are humankind's

chief possibility for a unified future. A single glance at the United States' space program by even a mildly interested observer would reveal its international texture, as the U.S. launches equipment supplied by German, Canadian, Indian, or Japanese manufacturers. The celebrated arm of the Shuttle is a Canadian contribution, and many satellites launched so far are of international origin.

Before resigning from the Jet Propulsion Laboratory, Bruce Murray spoke of the need for an international flavor in our ongoing activities in space, and I believe this is our best hope for what has been called a "moral equivalent to war." What better place to reach beyond our petty self-identifications as separate nations and to enter a new era of viewing ourselves as the single human race?

David Benefiel
Walla Walla, WA

behind the scenes | keeping in touch

How do you keep in touch with astronomical events going on around you? I don't mean elongations of Mercury and oppositions of Jupiter — I mean meetings of astronomical societies, clubs, and space groups. Maybe you think that most of those meetings don't interest you — but who knows when one will?

Well, one place to look is our AstroCalendar on the last page of *AstroNews*. (In this issue, it's on page 64.) AstroCalendar offers a schedule of upcoming events — mostly meetings and symposiums — for both amateur and professional astronomers. Each listing provides a brief description of what kind of meeting it will be plus the name and address of someone to contact for more information.

If your group is doing something you want a lot of people to know about, send your listing to "AstroCalendar" at least four months (and preferably six months) in advance so that we can be sure it will appear in time for our readers to respond. Then be prepared for a big response.

Another place to keep in touch is through our AstroMart listings. That's where we run notices of events with local or regional interest — a membership drive for a new astronomy club, or an announcement that an established club's meetings are held at such and such a place on the third Friday of every month. Of course,

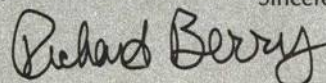
we also run "For Sale" and "Wanted" notices from individuals.

To take advantage of this reader service, send us a note or card with your announcement printed neatly on it, to "AstroMart Freebies." We try to make sure that each listing is fresh, so we will not automatically reinsert these notices at intervals — you must send us a new card. By the way, no commercial announcements are allowed, and, of course, we reserve the right to reject any notice.

Now, with all this talk of sending stuff in, we'd like to remind everyone of our photo submission policy. You realize, of course, that many of the pictures we run come from readers like yourself. From those that you submit, we pick the ones that we feel will best show other readers what's going on in the sky.

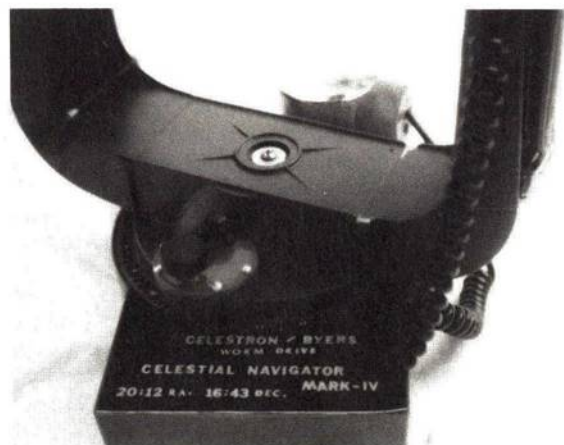
And you've probably noticed our monthly "Best Astrophoto" contest. There are no special rules to enter the contest — when you send us pictures, they're automatically entered. Once they're in our files, they could win, whether you sent them last week or five years ago. This month the winner's on page 78. By the way, each winner gets a check for \$100!

Sincerely,



Richard Berry
Editor-in-Chief

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ROGER W. TUTHILL, INC.

discover the pleiades

gazer's
gazette

by
Gail O. Clark

Nearly everyone who has looked up at the sky has seen — and perhaps marveled at — an elegant open star cluster in the constellation Taurus. A rich collection of stars spanning more than a degree of sky, the curious luminous patch has held many names throughout history, but is best known as the Pleiades, or “Seven Sisters.” First becoming visible low in the eastern sky on frosty autumn evenings, the Pleiades cluster is the most renowned, brightest cluster of stars in the entire sky and one of the best deep-sky objects. The gleaming suns, glowing with barely subdued grandeur, require no hunting or searching even for observers unacquainted with the night sky: indeed, when it is above the horizon, the Pleiades cluster is one of the most conspicuous sights visible.

As autumn dissolves into winter, the Pleiades (recorded as entry 45 in Charles Messier’s famous list of nebulous objects) climbs higher in the wintery blackness

until on evenings in deepest winter it rides nearly overhead. As the year progresses, the cluster slowly moves toward the western horizon, eventually fading into the glare of the setting Sun in the spring, not to show itself again until another autumn evening.

To the naked eye, the lustrous galactic cluster appears to be about twice the size of the Full Moon, and resembles a small, dipper-shaped grouping of six stars, complete with a stubby handle. In fact, uninitiated sky watchers often mistake the Pleiades for the Little Dipper. The true Little Dipper, of course, is the constellation Ursa Minor which contains Polaris, the Pole Star.

Although it is pleasing to the naked eye, the Pleiades cluster is transformed into a more glorious sight when viewed with binoculars or a wide-field telescope. Steadily held binoculars probably offer the best views of this celestial gem — they frame the group well and show it as a

multitude of bluish-white diamond points suspended against the inky blackness of space. Rich field telescopes, those of short focal length and comparatively low magnification, offer superb, all-encompassing views of the gleaming stars. Large instruments typically do not show the Pleiades very well, as the cluster spills over their comparatively small fields of view.

In 1886, Isaac Roberts’ success in photographing the Pleiades set off a rash of such attempts. Long exposures made it clear that the colony of stars was enveloped in a misty haze, particularly

To an observer standing outside on a cold winter’s night, one of the most easily visible sky objects is the Pleiades, a tiny dipper-shaped patch of 6 naked-eye stars. A few observers distinctly separate eleven individual stars; how many do you see? Photo by Fred Hafeli with a 50mm lens and a 2-minute exposure.







Above: Small telescopes at low power show the Pleiades as a sparkling cluster of bluish-white suns with many tiny double stars and star chains — and perhaps even some reflection nebulosity. Paul Roques made this photo with a 4-inch f/2.64 Schmidt camera and hypersensitized TP 2415 film. **Left:** Now too big to fit into a single field of view, M-45 viewed with a large instrument is a multitude of tiny stars enveloped in ghostly pale nebulosity. Photo by Martin C. Germano using an 8-inch f/10 SCT, 103a-F emulsion, and a 70-minute exposure.

around the star Merope, evidently glowing from the reflected light of the stars embedded in the gossamer cloud. Since then, many sharp-eyed observers have visually detected the faint wisps of nebulosity, the brightest part of which is NGC-1435. But such sightings are becoming rare as increasing light pollution and particulate matter in the atmosphere overwhelm all but the strongest starlight. Today, only in areas far from population centers — and under the darkest and most transparent skies — can the ghostly nebulosity be glimpsed. The glowing matter surrounding the Pleiades is composed primarily of tenuous gas and dust, the stuff of which stars are made. Over eons of time and under the critically precise conditions necessary for starbirth, infant suns condense out of such interstellar primordial material. The faint tracers of nebulosity in the Pleiades are

the remnants from 20 million years ago when the cluster's stars blossomed into empyreal brilliance.

With the invention of the telescope, the Italian astronomer Galileo sketched the Pleiades on several occasions with his prized "optick tube." He identified 36 stars and assumed that they were members of a common family. Today's astronomers estimate that there are approximately 500 stars in the Pleiades system. Though it appears small from our earthly vantage point, the cluster lies 410 light-years away, and is consequently immense. The group measures 20 light-years across: even at the ultimate attainable velocity, the speed of light, an interstellar trek from one edge of the cluster to the other would require nearly a quarter of a century. The light you see from the Pleiades tonight has traveled through cold black space since before Galileo marveled at the sparkling white suns. The starry sentinels are comparatively young on the stellar evolutionary scale, having attained the age of only 20 million years or so. Yet most of the Pleiads have about 80 million years of life in them before their fueling nuclear fires subside and fade into cold, blackened stellar ash.

The Pleiades' stars are young, hot, supermassive, and furiously violent compared to the likes of our mild mannered Sun. Alcyone, the brightest member of the group, is about 1000 times brighter and 10 times larger than the Sun. And though they are moving through space together at 90 thousand miles per hour — about 25 miles each second — the motion of the Pleiades goes unnoticed over the relatively brief span of a human lifetime. In fact, 30,000 years will pass before the Pleiades will move a distance equal to the apparent width of the Full Moon.

The seemingly static, motionless appearance of the cluster triggered a curious notion in 1846 when Johann Heinrich von Maedler, a German astronomer, made a startling pronouncement. Based upon the apparent absence of motion of the cluster, the enthusiastic observer informed the world that Alcyone was the "central sun of the universe." The idea gained little support and shortly thereafter was proven grossly inaccurate.

Although at any given moment stars appear timeless and unchanging, a persistent allusion to a lost Pleiad threads through the literature and legend of the cluster. Given usual sky conditions it is possible for someone with average eyes to discern six stars with no optical aid. Nonetheless, the number seven is referred to for centuries, making the presumed missing or lost Pleiad something of a modern mystery. There is a possibility that one of the major stars in the collection has diminished in brightness and is no longer visible to the naked eye. Pleione, one of the brighter Pleiads, is known to be a

variable star whose brightness has changed by up to a half magnitude, a detectable amount to a sharp eye. Perhaps Pleione is responsible for the enigma of the lost Pleiad.

Imagine for a moment being an inhabitant of a planet circling one of the brighter stars in the Pleiades system. Stepping outside at night would be a singular experience — the sky would be indescribably alive with the cold, blue luminescence of the sister stars of your Pleiad "sun." Gone would be our Moon and its cold, feeble light. The massive hot stars of the cluster would litter the sky, causing an eerie omnipresent glow that wouldn't go away. It certainly wouldn't be conducive to good astronomical observing!

The world's literature mentions the cluster quite often, and compares it to such varied things as a rosette of diamonds, shining dew drops, a bunch of grapes, and even a herd of cosmic camels. Familiar to many are Tennyson's words, "Many a night I saw the Pleiades, rising thro' the mellow shade, Glitter like a swarm of fireflies tangled in a silver braid." J.R.R. Tolkien, in *The Hobbit*, imaginatively referred to them as the "netted stars." Polynesian culture knows the cluster as *matariki*, or "little eyes." Homer wrote of Ulysses sailing from the isle of Calypso and being situated "... at the helm, keeping his eyes upon the Pleiades." Further, the storied Pleiades hold the singular distinction of being the first stars referred to in the writings of ancient astronomers — the cluster was described by Chinese writers as early as 2357 years before the birth of Christ.

The Pleiades has influenced various earthly cultures as well. Called the "hoeing stars" in South Africa, their appearance in the evening sky signals the time for cultivation of the land in southern hemisphere countries. Moreover, some respected scholars suggest that the seven chambers of the Great Pyramid were built to commemorate the Pleiades.

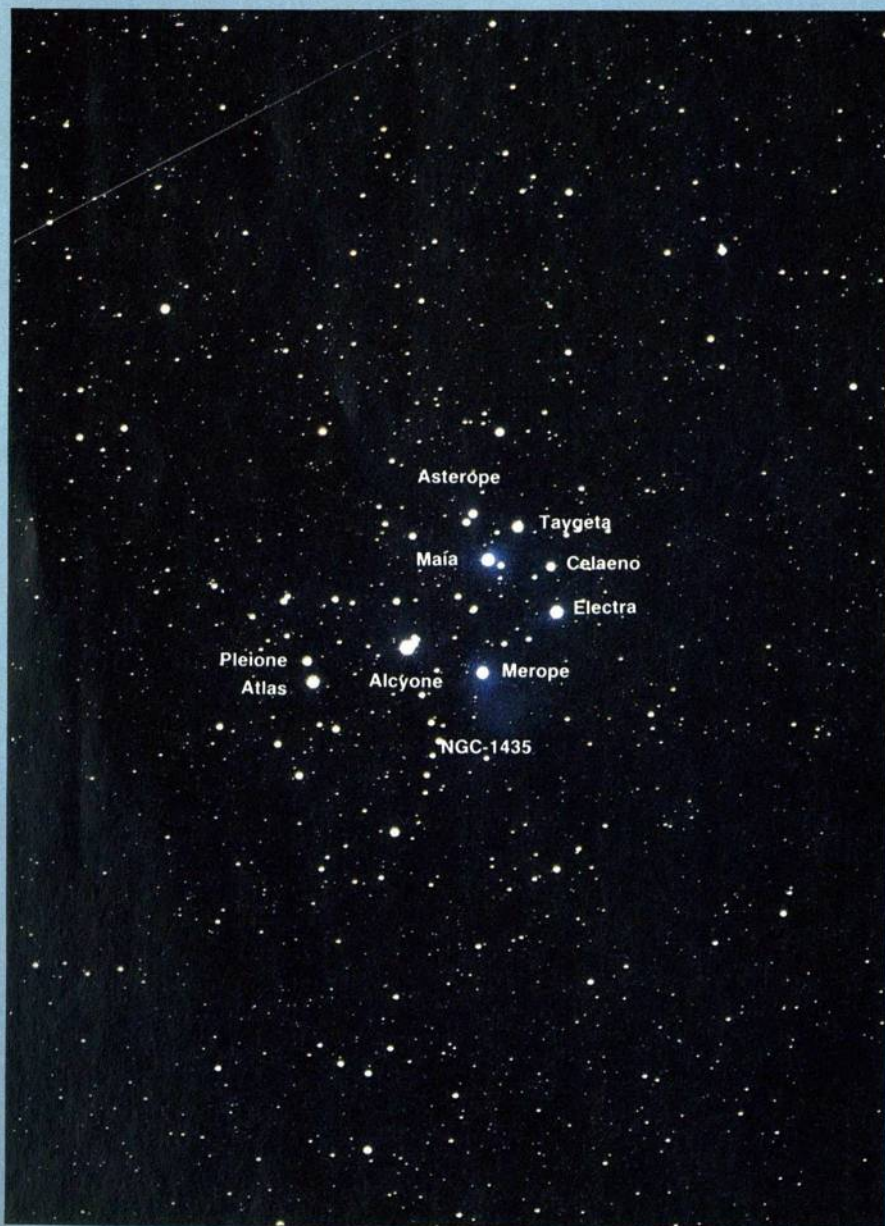
Other than in the general vicinity of the northern pole star, Polaris, stars appear to rise in the east, make a leisurely circuit across the night sky and finally set in the west, just as our Sun transits the daytime sky. As each star traces its celestial arc from horizon to horizon, there is an instant at which each attains its greatest height in the sky prior to beginning its westward slide down the firmament. This stellar high point, called *culmination*, occurs precisely at midnight only one time during each year.

Midnight culmination of the Pleiades was an exceedingly important event in the lives of many primitive people. For some, this was the point at which their annual calendar began; others believed this once-a-year event to be a time of dread and foreboding. Some ancient cultures thought midnight culmination of the cluster to be related in some manner to blindness and loss of sight. In Europe, during the Middle

bright stars in the pleiades

Star	Name	Mag.	Spectral Type
η (25 Tau)	Alcyone	2.9	B7e III
27 Tau	Atlas	3.6	B8 III
17 Tau	Electra	3.7	B6e III
20 Tau	Maia	3.9	B7 III
23 Tau	Merope	4.2	B6 IV
19 Tau	Taygeta	4.3	B6 V
BU (28 Tau)	Pleione	5.1	B8e p
16 Tau	Celaeno	5.4	B7 IV
21, 22 Tau	Asterope	5.6, 6.4	B8e V, B9 V
18 Tau	—	5.7	B8 V

The mythical "seven sisters" are, from brightest to faintest, Alcyone, Electra, Maia, Merope, Taygeta, Celaeno, and Asterope. The brightest patch of nebulosity — which surrounds Merope — is NGC-1435. In this photo by Bill Iburg, the streak of a Perseid meteor is at top left.



Ages, midnight culmination of the Pleiades became the traditional date of the sinister Witch's Sabbath, the forerunner to modern day Halloween.

Myths and legends connected to the famous colony of stars abound in the folklore of many cultures. Early Teutonic nations had a popular myth which told of the Saviour strolling past a bakery shop one afternoon. Attracted by the savory aroma, he stopped and requested a loaf of the freshly baked bread. The baker refused, but his wife and six daughters secretly honored the request. As a reward for their generosity, the seven were placed in the sky to forever reside there in starry splendor.

Devil's Tower, the imposing natural rock formation in Wyoming, is linked to the Pleiades. According to American Indian lore, the Great Spirit erected the rocky structure to aid in the escape of seven Indian maidens being pursued by a giant bear. The nimble maids were able to scramble to safety atop the pinnacle and from there fled into the heavens where they reside today. The remarkable vertical striations and cracks on the sides of the sheer, rocky prominence were caused, according to the legend, by the sharp claws of the bear as it strained to reach the fleeing Indian maids.

The sparkling cluster has also acquired a measure of down-to-earth utility. The Japanese word *subaru*, translated literally, means Pleiades. A silvery, stylized representation of the distinctive cluster appears on the exterior of each Subaru automobile produced.

What of the future? Will the Pleiades live out their stellar existence in luminescent splendor, untouched by time? Of course not. Open star clusters are fairly temporary as compared to galaxies or globular star clusters. As it whirls about the center of the Milky Way, the Pleiades cluster will eventually be torn apart by the gravitational tug of other stars. Less likely but possibly sooner fates include disruption by a passing star, a supernova explosion nearby, or a maverick Pleiad leaving the group.

Whatever the destiny of the Pleiades star cluster, it is a sight that can inspire everyone. Certainly one of the most impressive objects in the heavens, this legendary deep-sky object is a joy to gaze at, whether for aesthetic pleasure, intellectual stimulation, or simple relaxation. Go out on the next clear night and take a long hard look at the Pleiades with binoculars, a small scope, or simply your eyes. Remember that you're looking at an enormous aggregation of hot young stars whizzing by in space — truly one of nature's grandest shows.

Gail Clark is a co-founder of the Pocatello, Idaho Astronomical Society and a frequent contributor to "Astronomy Reviews." His last article in ASTRONOMY was "Starting an Amateur Astronomy Club," in October 1981.

ASTRONOMY REVIEWS

The Measure of the Universe

Isaac Asimov

339 pages, hardcover, \$15.95
Harper & Row (1983)

Titling a book *The Measure of the Universe* is pretty ostentatious; it implies that the author has indeed measured the universe. Given that, it's no surprise to find Isaac Asimov as the author!

Most of us have been reading Asimov's books for years, and for many, an early interest in science is traceable to his writings. I have come to expect quality work from him. This book, however, was not as good as his usual work — it was slow-moving at the start and trivial at times, and it won't rank as one of the good doctor's better efforts. It was worth finishing, though, particularly after I got through its first two sections.

The book has nine main sections dealing with length, area, volume, mass, density, pressure, time, speed, and temperature; it uses SI (Système International) units — better known as the metric system — almost exclusively. The only mention of customary (Imperial) measurements comes at the start and in a few rare comparisons.

Asimov employs an exponent system to increase and decrease the figures from the familiar measurements (one meter, one second, etc.) to the less common and more impressive measurements (100 million seconds ago, for example, the biblical Gideon was fighting his battles with the Midianites). In this regard, the book succeeds because it vividly conveys both the immensity and minuteness of the universe.

Asimov begins with length and progresses from the basic measure of one meter (a two-meter-tall person's stride is about one meter long) to one billion exameters (10^{27} meters; the universe is 750 million exameters in circumference). Having finished our progression upward, Asimov then turns and leads us down the ladder of length. Again starting with one meter and working smaller, Asimov winds

up by telling us that the diameter of a proton is 100 femtometers, or 10^{-13} metres.

The sections on volume are almost exclusively about astronomy. Meteor Crater in Arizona was formed by a meteorite that may have had a volume of 8,000 cubic meters. Another possible meteorite strike may have occurred in northern Quebec, Canada; it would have had a volume of over a cubic kilometer.

The most interesting sections of the book deal with time and history. One estimate placed the biblical account of creation at 4004 B.C., just 300 billion seconds ago, while by another account — that of the Big Bang — creation occurred 15 billion years ago.

On the smaller end of the time scale, a nerve impulse travels from the brain to the hand in one centisecond (0.01 second), a beam of light will travel 300 km in 0.001 second, and in 100 nanoseconds (10^{-7} second), light travels the distance of two average-sized houses.

The surface temperature of the hottest star may reach $50,000^{\circ}$ Kelvin. On the other extreme, the lowest temperature attained in the laboratory is 0.00000005° Kelvin — just one twenty-millionth of a degree away from absolute zero.

On the whole, I found the book very interesting. Loaded with facts and figures about astronomy, it presents ordinary information in new and novel ways, which helps you get a fresh grasp on what the figures mean. If you can work your way through the first few sections, you'll probably be delighted with Asimov's free-flowing style and his vast reservoir of knowledge. *Michael Ray.*

Astrophotographie: Les Techniques de L'Amateur

Patrick Martinez

212 pages, paperback, 157F

Société d'Astronomie Populaire (1983)

This French book on amateur astrophotographic techniques covers a

wide variety of topics, including solar, lunar and planetary photography, deep-sky photography (including the use of hypersensitized emulsions), meteor photography, and spectrography. The book tells you — if you understand French — how to use filters, Barlow lenses, and other accessories, as well as how to guide well and compose your shots. A color section, containing examples of deep-sky work, appears in the middle of *Astrophotographie*, which costs about \$20.

365 Starry Nights

Chet Raymo

225 pages, paperback, \$12.95

Prentice-Hall, Inc. (1982)

365 Starry Nights is a book for uninitiated stargazers — beginners who want to be introduced to the wonders of the universe. It is a book that takes a novel, somewhat unusual approach to introducing the sky: it befriends the reader, takes his hand, and guides him through the sky over the course of a year, discussing a different star, constellation, or concept with each night's entry.

The entries are mini-essays, often completely independent of each other and tied together only through the theme of passing time. For example, on September 8th we learn about the Dumbbell Nebula in Vulpecula and discover the nature of planetary nebulae in general; on September 12th we hear about Cepheus the King and his star lore, and on September 22nd we find out that Polaris won't always be the pole star and that long ago Thuban in the constellation Draco held the position. In spite of the broad topical coverage, the book reads smoothly.

Author Raymo takes advantage of a slick repertoire to relate constellations and what they hold, their lore, and ideas of modern astrophysics. Raymo also discusses semi-technical concepts with the enthusiasm and crystal-clear understandability of a

10-year old talking about the latest *Star Wars* episode. Speaking of Cygnus in the August 16th entry, Raymo states: "On a summer's night you can almost hear the beating of the swan's wings as the great bird traverses the zenith." His dose of pertinent information in addition to a literary smoothness makes the book useful and a joy to read or simply page through. It is illustrated on every page with large, slightly goofy line drawings that are perfect for their purpose — they give the book a light, not-too-serious "homey" feel.

This type of book could easily have fallen short had it not been carefully thought out and well-produced, but Raymo has succeeded in putting together a rare book: one that is informative, entertaining, and unique. *David J. Eicher.*

More Uses for Your Timex/Sinclair 1000 Astronomy on Your Computer

Eric Burgess and Howard J. Burgess
153 pages, paperback, \$8.95
Sybex (1983)

This book provides 20 programs, ranging in length from 71 lines to 793 lines, that can be keyed in and run on any Timex/Sinclair 1000 (same as the Sinclair ZX-81) with 16K of memory. They will also run on the new Sinclair Spectrum.

The programs are arranged into four sections: Time, The Moon, The Planets,

and General and Tutorial. Under "Time" are programs that compute the date of Easter for any year; convert local mean into local sidereal time; convert calendar date to Julian date (and back again); precess coordinates; and compute elongations and transits of Polaris.

"The Moon" offers programs giving the r.a. and dec. of the Moon (rounded to tenths of an hour of r.a. and to the nearest whole degree of declination); time of rise, transit, and set for any date; the date of the first umbral (total or partial) lunar eclipse of a given year; and the phases of the Moon over any two-month period you choose in any year.

"The Planets" provides routines for computing the approximate r.a. and dec., heliocentric longitude, and distance (in AUs) from Earth of the planets; the angular diameter and distance of Mars for any date (and its next opposition); elongations, phases, angular diameters, and distances for Mercury and Venus; rise, transit, and set for the Sun, Moon, and planets; horizon plots of the same; plots of the Sun, Moon, and planets in relation to the zodiacal constellations; and the locations of the Galilean satellites of Jupiter.

The last section offers three programs that perform conversions (parsecs to light-years, decimal degrees to degrees, minutes, seconds, and back again, etc.); give you a name-that-constellation game; and perform astrophotographic exposure calculations.

The book amounts to a TS-1000 version of the senior author's earlier book for Apple-owners, *Celestial BASIC* (see *Astronomy Reviews*, April 1983). In fact, in their preface to this book, the authors advise readers to get a copy of *Celestial BASIC* if they want more background information on the subjects covered by the programs and if they want to explore other ways of writing the programs. Provided the reader just keys the programs in and runs them, this is not really necessary, since the book is self-contained in all its essentials.

But the problem with the "economical" approach — and Sybex is not the only publisher to use it — is that beginners often end up dreadfully confused, since many are forced to use the book as a "black box" due to inexperience. Although it increases the bulk and price, I think the best books of software are those that err on the side of inclusion. No software book can be an astronomy primer, but besides listing the program, the book should also give some explanation of how the formulae used really work and what their limits of accuracy are. This will help beginners get squared away, and more experienced programmers will be shown where they can go in and customize a program efficiently.

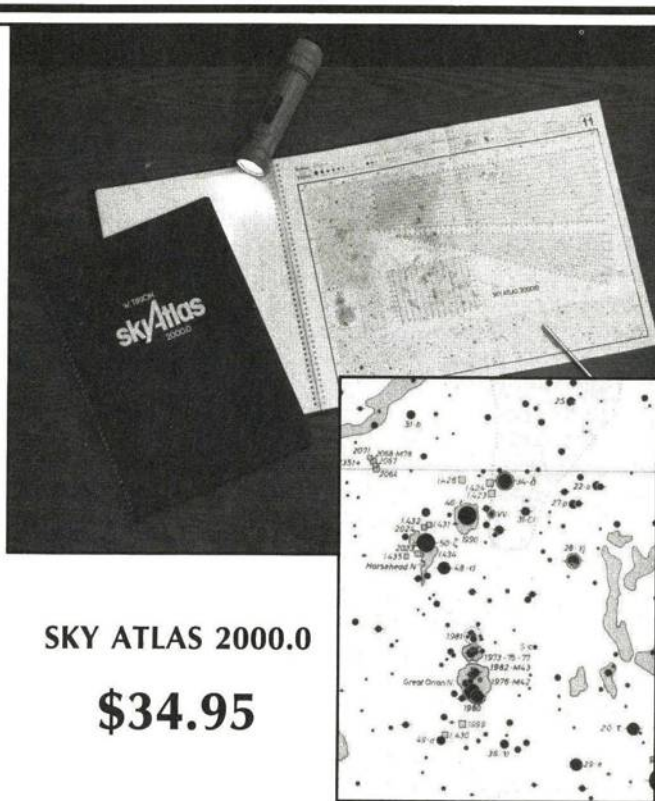
In short, this book (like so many others on the market) is pretty good, though still shy of what it ought to be. As of the date

Sky Atlas 2000.0

Join the ranks of knowledgeable amateur astronomers with the **Sky Atlas 2000.0**. Find your way to galaxies, star clusters, and nebulae with ease. These giant star maps are crisp and distinct — and they're beautifully illustrated in color. Even the arm-chair astronomer will enjoy tracking down favorite nebulae and galaxies and other celestial objects seen in *ASTRONOMY*.

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of writing, it has no competitor, so any TS-1000 owner who's interested in astronomy will certainly want a copy. But if you're interested in the full story, in knowing how these routines operate, it'll disappoint you. *Robert Burnham.*

The Visibility of Deep-Sky Objects

Fred Klein

283 pages, paperback, \$28.95

Klein Publications (1983)

[publisher's address: 12225 Magdalena, Los Altos, CA 94022]

This 5-volume set of reference works for deep-sky observers lists data for over 2,400 stars, clusters, nebulae, and galaxies, published in computer-printout fashion. Volume 1 contains information such as object type, coordinates, magnitude, size, approximate surface brightness, which atlas charts to use, etc., for about 500 of the brightest deep-sky targets. It categorizes objects by right ascension, visibility, and object type and sells for \$7.95 by itself. The second and third volumes — sold together for \$12.95 — make up a set that provides information on over 2,400 objects: Volume 3 contains galaxies, and volume 2 everything else. The fourth and fifth volumes contain data on the same objects as volumes 2 and 3, but list them by chart numbers for the *Sky Atlas 2000.0*. The final two volumes, as a set, cost \$12.95.

The Origin and Evolution of Planetary Atmospheres

A. Henderson-Sellers

240 pages, hardcover, \$34

Adam Hilger (1983)

Atmospheres in the solar system can range from the extremely tenuous and transient (such as the Moon and Mercury) to the near-stellar (such as Jupiter). The problem confronting astrophysicists is to make sense out of this diversity. The author organizes his discussion around several topics: origin of planets, evolution of atmospheres, Earth's atmosphere, planetary climatology, and stability of environments. The reader is assumed to be comfortable with some college-level math and chemistry.

Man on Earth

Charles Sheffield

160 pages, hardcover, \$29.95

Macmillan (1983)

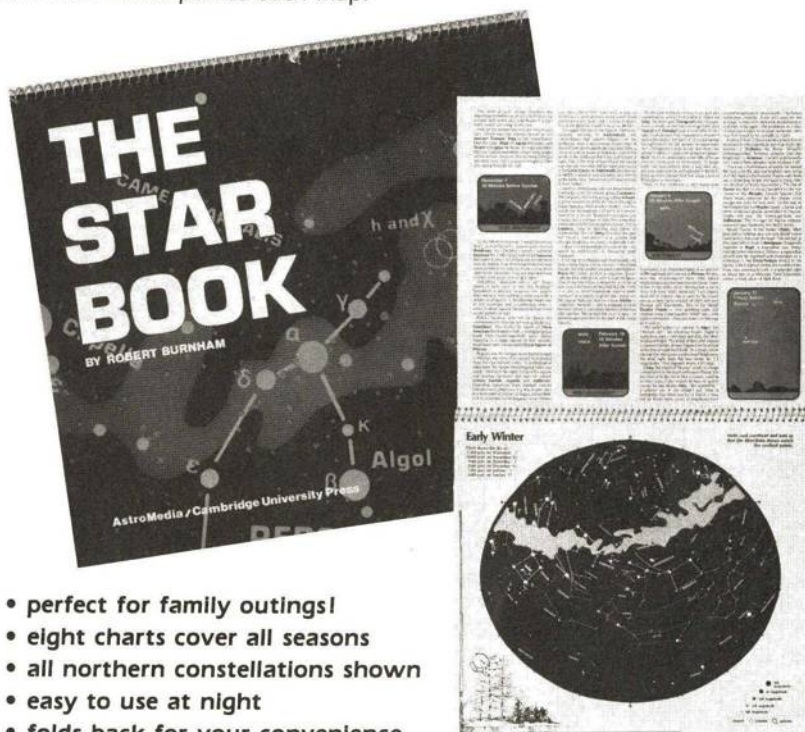
Like *Earthwatch*, Sheffield's previous book, *Man on Earth* presents a generous selection of Landsat images of Earth. But this time they focus on ways mankind has altered his surroundings and how they show up from orbit. Accompanying each photo is a descriptive text and an index map that labels the objects in the photo.

November 1983

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eye on the sky

juno reaches opposition

by Fred Schaaf

the wanderers

Once again, Venus is the single most interesting planet of the month. In addition to reaching a superbly placed greatest elongation, our sister world undergoes several close conjunctions with naked-eye stars. Most of the other planets suffer from their proximity to the Sun in the sky, but present a few notable sights as they march on towards their great gathering at year's end.

Neighboring **Venus** continues to increase its distance from us, dimming very slightly, but its face still appears half illuminated in telescopes around November 4, the time of greatest western elongation. The planet's 46.5° elongation, slightly more than that shown in June, occurs when Venus is far north of the Sun — and therefore very much higher in the sky for North American and British observers than it was in June.

As a matter of fact, this elongation features Venus at almost its best possible position for mid-northern latitude observers. At sunrise, the planet is about 44° above the horizon for a latitude of about 40°N — nearly halfway to the zenith! That translates to about four hours of visibility before sunrise in early November, and not much less even by month's end. Venus will not be quite this well placed for northern observers until it becomes the "evening star" in 1988, and then once again as "morning star" in 1991 (the 8-year cycle — 1983 to 1991 — in Venus events).

This may be an unusually good apparition of Venus, but consider the current opposition of another solar system body. Although the minor planet **Juno** will require binoculars, this opposition presents a fine opportunity for seeing this strange world. Roughly once a decade,

Juno's closest approach to Earth occurs near its perihelion, which makes the asteroid as bright as magnitude 7. Even so, Juno is now unusually bright.

About a week after its October 22 opposition (its oppositions occur almost 15 months apart), Juno shines at about magnitude 7.2 — it will not be nearly this bright again for more than a decade, and not even marginally brighter until the year 2008. Only twice in the 20th century has Juno just barely outshone its magnitude this fall, the best being a magnitude 7.1 as recently as 1970.

Juno ranges from 1.05 AUs from the Earth at the current encounter (closer than

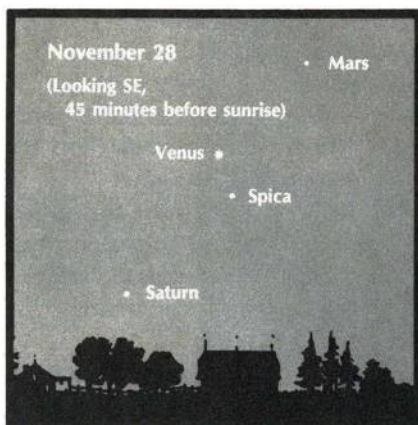
6, Venus will be less than 2 minutes of arc north of Beta Virginis. Then just a week later, on the American afternoon of the 13th (excellent for Britain), Venus will pass less than 4 arc-minutes south of Eta. These stars are brighter than Ganymede and Callisto ever get, but Venus is far brighter than Jupiter — and a full eight magnitudes (1600 times) brighter than the two stars. You'll really need binoculars to observe the closest approaches. How soon before and after those times can you detect the two with your eyes?

The planet's conjunction on December 17 is not quite so close, but is far more interesting: an encounter with **Saturn**. Just a day past conjunction with the Sun as November starts, Saturn gains altitude so rapidly that by the middle of the month it rises near the beginning of morning twilight, well over an hour before sunrise.

Saturn has at last crossed over the border from Virgo to Libra, but even speedy Venus only manages to reach Spica by month's end. Venus is 4° north of that first magnitude star (slightly dimmer than Saturn) on November 29, when the pair will lie near another fine duo: the Moon and Mars. Overnight the lunar crescent will leap to the vicinity of Venus and Spica, forming another fine scene with Mars above and Saturn below the main gathering.

Mars has moved away from Venus, and there will be no more conjunctions between them until 1985. Still little brighter than Polaris, the Red Planet now begins one of its brightening trends — by May it will easily outshine Sirius.

Our final important planet this month is **Jupiter**, which on the evening of November 6 lies low in the southwest near the Moon after sunset. Jupiter, now supposedly dimmer than Sirius,



any of the other "Big Four" asteroids — Ceres, Pallas, and Vesta — get to us this decade) to as much as 4.32 AUs during the 1980s. This extreme variation is due to the asteroid's eccentric orbit: at its next perihelion (Dec. 30, 1983) it is 1.98 AUs from the Sun, but at its next aphelion (in 1986) it is 3.36 AUs out from the Sun. Its maximum magnitude at that year's opposition just reaches 10.0!

Juno is not the only November sight you'll want binoculars for. Venus has close conjunctions with two roughly 4th magnitude stars in Virgo, Beta (β) and Eta (η). The first event is the best. At about 6 a.m. Eastern Standard Time on November

At the base of an auroral curtain, it's easy to imagine the deluge of electrons making the atmosphere glow. Forrest Baldwin of Wasilla, Alaska, used 400 speed film, a setting of $f/2$, and a 9-second exposure to catch this auroral cascade.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.



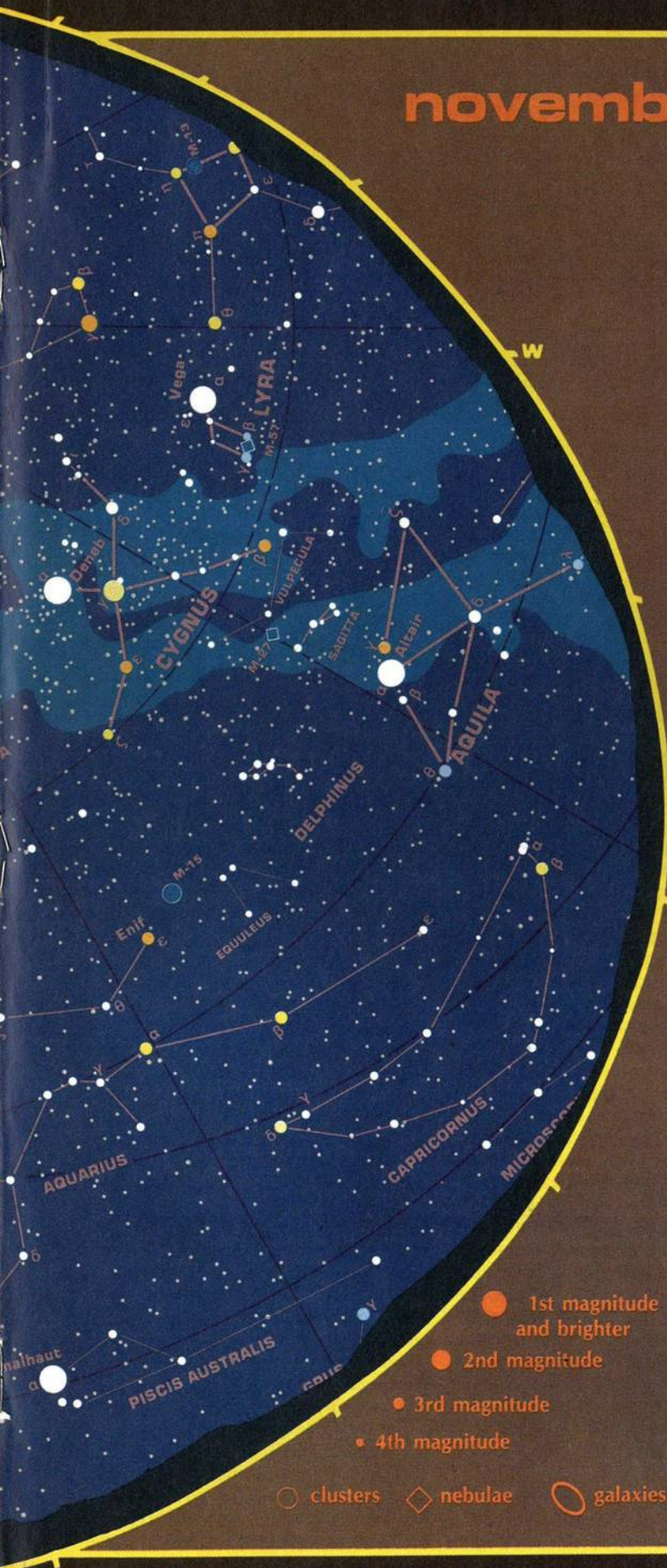
star dome

The
Star Dome
shows how the
sky looks at:

- 9:15 p.m. local time on Nov. 1
- 8:15 p.m. local time on Nov. 15
- 7:15 p.m. local time on Nov. 30



november sky almanac



4th New Moon is at 5:21 p.m. EST. Also, Venus is at greatest western elongation (47°) from the Sun; look for it high in the southeast during the hour before sunrise.

5th This morning is the time of peak activity for the Taurid meteors. From a dark-sky site, you'll see some 10 slow, bright meteors per hour coming from the Pleiades / Hyades region.

12th First Quarter Moon is at 10:49 a.m. EST. Also, the Moon is at apogee at 10:26 p.m. EST: 251,251 miles.

14th The early morning hours today are the time of peak activity for the Andromedid meteors, a moderately sparse stream from the area of sky to the northeast of M-31, the Great Galaxy in Andromeda. Look for about 5 to 10 meteors per hour from a dark-sky location.

17th The famous Leonid meteor shower is at peak activity today. You probably won't see a "storm" like that of 1966, but this shower is well worth watching, despite the nearly Full Moon that will interfere.

20th The Moon is Full at 7:29 a.m. EST.

25th The Moon is at perigee at 9:23 p.m. EST: 229,822 miles. Mercury passes 3° south of Jupiter in the evening sky, though they'll be very difficult to spot low in the west-southwest. Locate Jupiter, then look below it to find Mercury, a -0.4 magnitude dot of light that will appear dimmer and ruddier than Jupiter's -1.3 magnitude white gleam.

27th Last Quarter Moon happens at 5:50 a.m. EST.

30th Mars is at aphelion.



approaches the end of its evening visibility on November 25 when it is only about $2\frac{1}{2}^\circ$ north of -0.4 magnitude Mercury. (Mercury is peeking into visibility after sunset. This follows an entire November of gradual ascension from superior conjunction.) They appear just 15° from Sol, and set only about 45 minutes after it does, for most of us. It will be impossible to observe the earlier conjunctions of Mercury with the small globular cluster M-80 (it passes 5 arc-minutes north of the cluster's center on the 18th), and with Uranus and Antares on the 20th. The unobservable conjunction between Uranus and Antares on the 22nd (almost 5° separation) is their last for about 84 years, the orbital period of that far planet.

Another good astronomical activity this month is meteor watching. During the first week of November there are bound to be a few Taurid fireballs to see. Also, there will be about an hour without moonlight before morning twilight on the 18th to look for five or ten of the swift and famous Leonid meteors.

the starry sky

No season in the sky has fewer bright stars than autumn — though, of course, that refers only to the convenient evening hours. If you wait a little later, you can see winter's traditional stars — the most

brilliant of any season — filling the eastern sky with their splendor. Despite their overall faintness, however, the autumn heavens hold the sky's brightest short-period and long-period variable stars, the north hemisphere's two brightest galaxies, and the most intrinsically impressive pair of open star clusters. And all of these attractions are visible to the unaided eye.

Finding our bearings with the **Great Square of Pegasus** (the rectangle of second magnitude stars high in the south or southwest on November evenings), we proceed from the upper left corner star of the square, **Alpheratz**, to find the extended glow of **M-31**, the Great Galaxy of Andromeda. For many of us, there is another way. M-31 lies at a declination of $+41^\circ$, so that if you live anywhere near 41° north latitude, it passes right overhead. At mid-month in November, go out at roughly 9 p.m. — the tiny glow at the zenith is the mighty fire of a spiral galaxy made of several hundred billion stars. It takes a distance of over 2 million light-years to turn the combined blaze of all these stars into the gentle and delicate fourth-magnitude glow now above your head.

About 500,000 light-years farther away than M-31, near the point of little **Triangulum** the Triangle, lies another member of our Local Group of galaxies: **M-33**. Some observers suggest that this 6th

Herbert De Vries and Robert Baumbach shot Ursa Major over Mackinaw, Michigan. Pictures like this are easy to take — all you need is a camera on a sturdy mount, fast film, and the ability to open the shutter for several tens of seconds.

magnitude object cannot be glimpsed with the naked eye, but experienced ones with very dark skies know better. Although astronomers have not found a gaseous connection between M-31 and M-33, it is possible that one exists — even though such a streamer would extend across a full 14° of our sky!

Just below Triangulum is another constellation whose most prominent stars also form a small pattern. This is **Aries**, the first constellation of the zodiac. Second magnitude **Hamal**, the constellation's only bright star, is a distinct orange in color. The area covered by the official boundaries of the constellation are much larger than the pattern suggests, and like the nearby northeastern part of Pisces it lacks any prominent stars.

The star forming the southeastern corner of the pattern of **Pisces** the Fish marks the knot in the string which ties the pair together. This star, third-magnitude **Alrisha**, is located not far from the brightest long-period variable star in the heavens — **Mira**.

Situated in the neck of giant **Cetus** the

Whale, Mira's name ("wonderful") reflects the remarkable behavior of this star. For most of each year it is too faint to see with the naked eye, and at minimum brightness it's even too faint for binoculars. But at an average maximum, which occurs usually about once every 11 months, Mira rises to third magnitude, similar to nearby Alrisha. In some years, Mira has put on an especially marvelous show by reaching second magnitude. At times like this, the strange star even rivals first-magnitude Aldebaran! (No wonder Chinese observers noted Mira near maximum well before the invention of the telescope.) Unfortunately, maximum brightness this year occurred back in summer, when the star was lost in the Sun's glow. By all means look for Mira, but don't be disappointed if you can't find it — by now it has probably faded from naked-eye view.

Here in the autumn constellations lies a bright variable star that never fades entirely from view. The second-magnitude star in **Perseus** is Beta (β) Persei, also known as **Algol**. Algol is an eclipsing binary, and about every three days the point of light we see fades in a matter of hours to third magnitude. This is an impressive sight, and perhaps it was noticed by some skywatchers in medieval and ancient times. Superstitions may have associated its disturbing behavior, seemingly so unlike other stars, with evil. Whatever the case may be, Algol means "the ghoul" and represents the severed head of the monstrous Medusa of Greek myth.

Now high in the north shines the bright letter "M" of **Cassiopeia** the Queen, and high in the northeast lies the "K" of Perseus. Right between these two examples of celestial calligraphy are softly glowing spots. This is the **Double Cluster** of Perseus — side-by-side clusters visible to the unaided eye in any reasonably dark sky. To the eye, they are a tantalizing pair, and even more fascinating in binoculars or rich-field telescope. Perhaps the most amazing fact about these clusters is that they are probably around 7,000 light-years away, in a spiral arm other than our own. What a splendid sight they would be if they were even so close as Rigel or Deneb.

But one of the closest open clusters now ascends beyond the southern end of Perseus. It is the lovely **Pleiades**, cluster of the Seven Sisters, followed by Aldebaran and the Hyades star cluster. Soon Capella and the other stars of winter will brighten our skies.

skylore

Much could be said about the lore on "shooting stars" in general and on individual meteor showers or storms. For this month, when we might see some bright Taurids, let's look at some of the legends and historical anecdotes about those rare "fireballs" (meteors brighter



than Venus) that reach the ground to become meteorites.

According to one translation, a list of treasures compiled by a Hittite king of the sixteenth century B.C. mentions "black iron of heaven from the sky." It is believed that the Hittites were the first to be successful at smelting iron, and the date usually given is about 1400 B.C. This skill gave them tremendous advantage in battle. Three millennia later, J.R.R. Tolkien first gave us the mythic stories contained in *The Silmarillion*, one of which involves a hero with a sword of meteoric iron. This was Turin Turambar whose sword "was made of iron that fell from heaven as a blazing star; it would cleave all earth-delved iron." At first this sword was called Anglachel, but later Gurthang, which meant "Iron of Death." It was the instrument of Turin's own death when the tragic hero asked the sword (which could talk, at least this once) if it would take his life.

Although Aristotle maintained that meteors were probably just vapors burning high in the air from time to time, many ancient Greeks and Romans knew that rocks fell from the sky and at least a few of them must have associated these stones with the bright streak in the sky. Plutarch noted that the size of the meteor (that is, the size of the incandescent envelope of air surrounding the solid mass) was much larger than the stones produced in the fall near Aegospotamus.

Livy says there was a fall of stones in Rome around 654 B.C. Pliny the Elder wrote that in 476 B.C. a stone the size of a chariot fell in Thrace. Even more impressive than a chariot-sized stone was the meteorite fall of 616 B.C. in China. The rock is supposed to have killed ten men and broken several chariots. (Did the Chinese have chariots then? Perhaps this needs a better translation.)

Today, Lincoln La Paz has collected the historic reports of buildings, animals, and people reputed to have been hit by meteorites. He assigns various ratings for the credibility of the reports. The earliest, given as "doubtful," is a meteorite found beneath the remains of a prehistoric megatherium, a giant South American

sloth. The most recent "certain" case of a person being hit on La Paz's list (some researchers consider this the *only* certain case) is the famous instance of the woman in Sylacauga, Alabama, struck by a meteorite on November 30, 1954. As far as remarkable strikes on buildings, of course, we have only to think of the meteorite which hit the house in Wethersfield, Connecticut, a year ago this month.

Many cultures have venerated meteorites. The black stone at the Mohammedan shrine of Mecca may be a meteorite. The temple of Artemis at Ephesus was one of the Seven Wonders of the ancient world and featured (perhaps was built because of) what seems to have been a sacred meteorite. The meteorite was still allegedly in existence at the temple when the apostle Paul came there. The Revised Standard Version of the Bible notes the words of the town clerk of Ephesus (Acts of the Apostles 19:35): "Men of Ephesus, what man is there who does not know that the city of the Ephesians is temple keeper of the great Artemis, and of the sacred stone that fell from the sky?" Meteorites have been found in an Aztec temple and in North American Indian burial mounds, too.

Yet the eighteenth century scientific community refused to believe that stones could fall from the sky. Apparently Edmond Halley's calculations of the great velocities and altitudes of certain meteors, and the clear conclusion that they must therefore come from outer space, were too hard to believe. Not until 1803 did the French Academy finally accept this conclusion on the basis of overwhelming evidence from their member Biot's study of the great meteorite fall in Laigle. Four years later, two Yale professors studied the fall of over 300 pounds of meteorite in December 1807 at Weston, Connecticut — a seemingly meteor-prone state! President Thomas Jefferson, who had considerable knowledge of astronomy, reputedly made this comment, typical of scientists of the day: "I could more easily believe that two Yankee professors would lie than that stones would fall from heaven."

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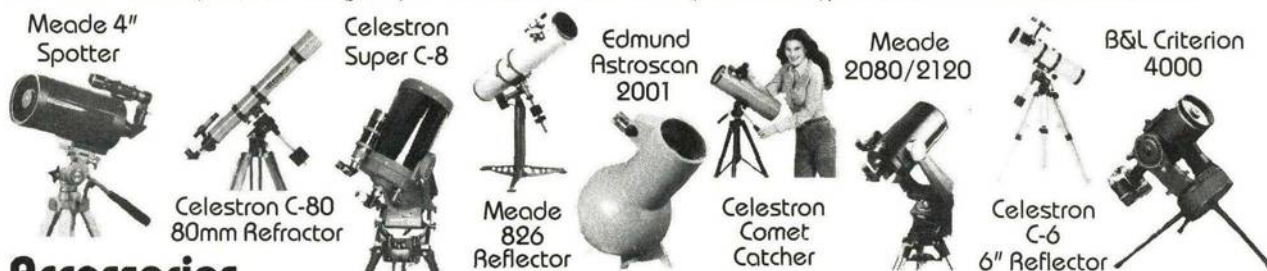
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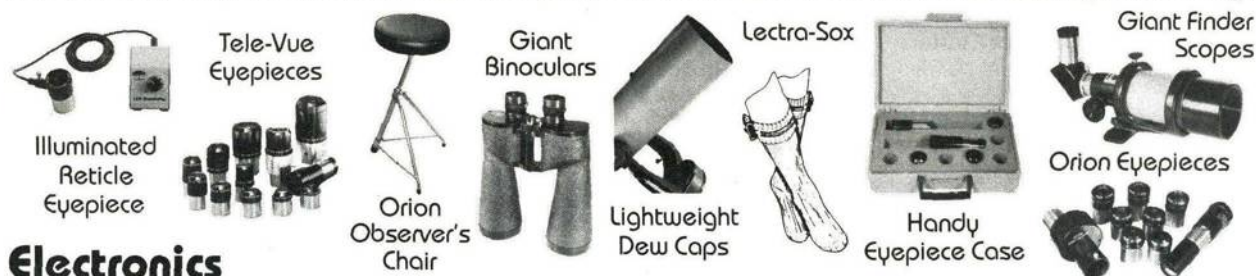
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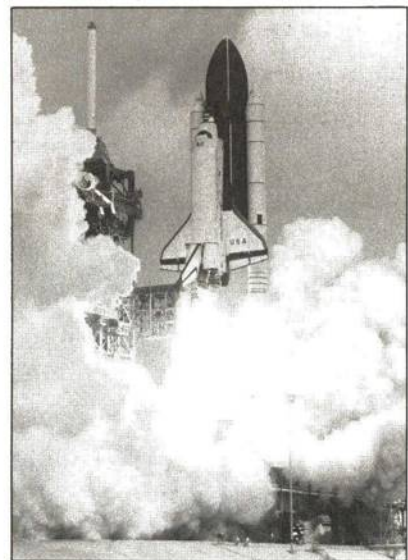
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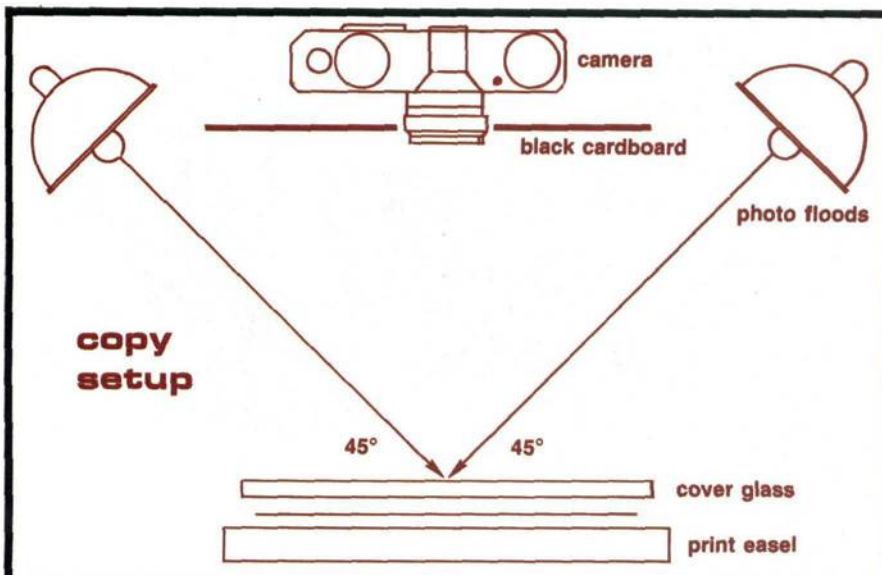
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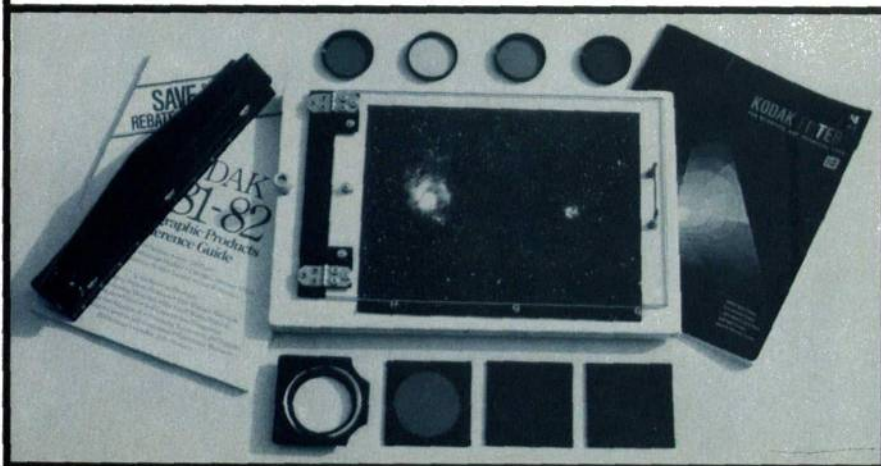
photography
in
astronomy

by
Jim Baumgardt



tricolor filters and exposures

	Red	Blue	Green
Telescope Filter	#25A	#44A	#8 + #44A (or #11)
Relative Exposure (clear = 1.0)	2.4	2.2	4.0 (3.2)
Printing Filter	#25A	#38A	#58
Relative Exposure (red = 1.0)	1.0	5.3	2.3



Color astrophotography can be a frustrating and tricky business — more so than black and white photography. After you load the scope and a half ton of gear in your car, drive for three hours to your dark-sky hide-away-in-the-mountain site, unpack and set up, polar align and test, you're almost too tired for the painstaking all-night guiding necessary to ensure top quality astrophotos. Color emulsions are very sensitive — you've got to expose for just the right amount of time, avoiding overexposure of sky background. And it seems as though you still come away with flat, greenish sky photos that you wouldn't show your wife, let alone your astronomy club pals. Yet you've been bitten by the astrophoto bug and you're determined not to let Murphy win out. "I'll be darned if I'm not going to match those photos in ASTRONOMY," you say. But what to do?

Well, it so happens that there may be a way out of your jam, even without fooling around with complicated techniques like hydrogen soaking or chilled emulsions. By doing so-called "tricolor" astrophotography, you can manipulate three routine black and white exposures of the same object — taken with different filters — into a single color image. (See "Tricolor Astrophotography," ASTRONOMY, December 1979.) Once practiced, the process isn't really complicated: All you have to do is produce good black and white images in your own darkroom.

Planning

Although it's based on a relatively simple idea, the tricolor process is a recent innovation in astrophotography. The idea is to take the image apart — in three colors — at the telescope and put it back together in the darkroom. To do this, you'll use three different filters — one red, one blue, one green — and three different exposures made using the same guide star. This is a great advantage over preexisting color films, since you can use spectroscopic emulsions like 103a-F or fine-grain films like TP 2415, both of which are far superior to color emulsions for detail and

speed.

I suggest using hypered Technical Pan 2415 (available commercially from several places) and processing it in the recommended way. I use a #25A filter for the red exposure, #44A cyan for the blue, and a combination of #8 yellow and #44A cyan for the green. (Incidentally, I've tried using gelatin filters for at-the-scope photography, but have found that glass holds up much better and costs less in the long run.) Substituting a #11 green filter in place of yellow and cyan allows a somewhat shorter green exposure with slightly greater overlap into the red end of the spectrum. TP 2415 isn't too sensitive in the blue end of the spectrum, so I've used cyan (a blue-green) for the blue frame to keep the exposure short.

Exposing

I've experimented quite a bit with exposure times for the different filters, and have come up with a set of "exposure factors." If a filterless exposure equals 1, red = 2.4, blue (cyan) = 2.2, green (yellow and cyan) = 4.0, and alternate green (#11) = 3.2. In other words, if you want to make a tricolor exposure of the Dumbbell Nebula and you normally expose hypered 2415 for 10 minutes, the exposure times you should use are 24 minutes (red), 22 minutes (blue), and 40 minutes (green) or 32 minutes (#11 green). You can multiply these factors for any exposure time you want.

If you place the filter between the lens or mirror and the film (in other words, inside the scope's light path), you'll have to focus the unit with the filter in place — especially if you use glass filters. Since it's difficult to focus with the red filter, substitute the cyan filter to focus and replace it with the red before exposing.

If you use a refractor, be careful: Chromatic aberration alters the focus with a change of filter type. This also causes registration problems during printing. You can generally ignore this effect with telephoto lens systems and other short-focus instruments, but traditional refractors cause problems. I suggest using Newtonians, Schmidt-Cassegrains with focal reducers (to speed up the exposures), or Schmidt cameras.

Printing

First, develop your negatives just as you always do. To print the negatives, you must be able to register them accurately. This requires building an easel: Mine is basically a wooden base with a hinged glass top to hold the paper flat. (See diagram on page 51.) It is equipped with three 1/4" diameter registration pins, available for a couple of dollars at drafting supply outlets or art stores. You will also need a good three-hole punch to ready the paper so that it matches the registration pins. I strongly recommend using a glass negative carrier in your enlarger to sandwich the negative flat. Not owning

one, I cemented two sheets of thin glass to a 2 1/4" negative holder, and it works well.

First make an 8" x 10" print of the red negative on smooth surface resin-coated (RC) paper, which seems to be far superior than regular enlarging paper. You must be careful to balance the three exposures — you can do this by printing all three with a sky background one shade above black. Try to keep the negative carrier glass clean. At first a little dust is only a minor hindrance — it shows up as a white spot on the prints. Later, however, it becomes more of a problem, and you will have to touch it up. After the red print dries, place it back in the easel and load the green negative in the enlarger. Move the easel as necessary to make the image of the green negative align exactly with the print. Now carefully remove the red print, replace it with a punched sheet of paper, and make the green print. Repeat this process with the blue negative, again using the red print for registration. You're free to use all the techniques of "normal" printing such as burning-in, dodging, or cropping.

Now you have three registered prints, one for each of the primary colors. Be sure to label each one on the back with the color it represents. (If they get mixed up, you'll come out with rather bizarre photos!) Now carefully examine your finished prints. Are there any dust marks

Below: A tricolor portrait in the making. Jim Baumgardt used his 6-inch f/4 Newtonian and hypered TP 2415 to make three exposures — a 28-minute green, 15-minute blue, and 18-minute red — of the Lagoon and Trifid Nebulae. Right: The finished product.







Again using a 6-inch f/4 telescope, the author exposed a red frame for 33 minutes, blue for 30 minutes, and green for 55 minutes and combined them to record subtle nebulosity around M-45, the Pleiades Cluster. The darkroom exposures were 3 seconds, 7.8 seconds, and 5.7 seconds, respectively.

or scratches? If so, now's the time to touch them up. This process is called "spotting" and is pretty easy. Get a bottle of touch-up liquid and a paint brush at the photo store. Dilute the liquid with a little water and "spot" the dust out by stippling it. This is worth considerable effort because dust marks or scratches on the final prints will be appallingly obvious — they'll look like bright red, green or blue marks suspended against a black sky.

The Tricolor Magic

Now you're ready to perform tricolor magic. You'll do this loading your camera with color slide or print film and recombining the three exposures by photographing them — through their corresponding color filters — onto a single frame of film.

Place one of the prints back in the easel, illuminating it with two photo flood lights set at a 45° angle. The color of the lights is important: I use type "BEP" lights, set four feet away from the print. I also put a one foot square piece of black cardboard

in front of the camera, with a hole cut for the lens. This keeps shiny parts of the camera from making "hot spots" on the print. Using a tripod, position the camera over the print and ensure that the entire print appears in the camera's field of view. (You may need a macro lens or short extension tube on the camera.) A copy stand is helpful but not necessary. I usually use Kodachrome 25 slide film and Wratten gelatin filters at this point — the filter numbers are #25A (red), #38A (blue), and #58 (green). If you don't use Kodachrome you may need different filters.

Exposure times vary with different setups, and you'll have to experiment to see what works best. For me they range from 3 to 15 seconds at f/32. The exposure ratio for the three shots (assuming red = 1): blue = 5.3 and green = 2.3. These ratios determine the color balance of the final print. You can adjust them. If the slide shows too much red, for example, reduce the red exposure time. Keep a record of exposure times for future use — it will prove invaluable.

To make the final picture, insert the red print in the registration easel, compose and focus the picture in the viewfinder, set the shutter on B (bulb), insert the red filter, and turn out the room lights. Be careful not to move the camera or easel from here on out. Lock the shutter open

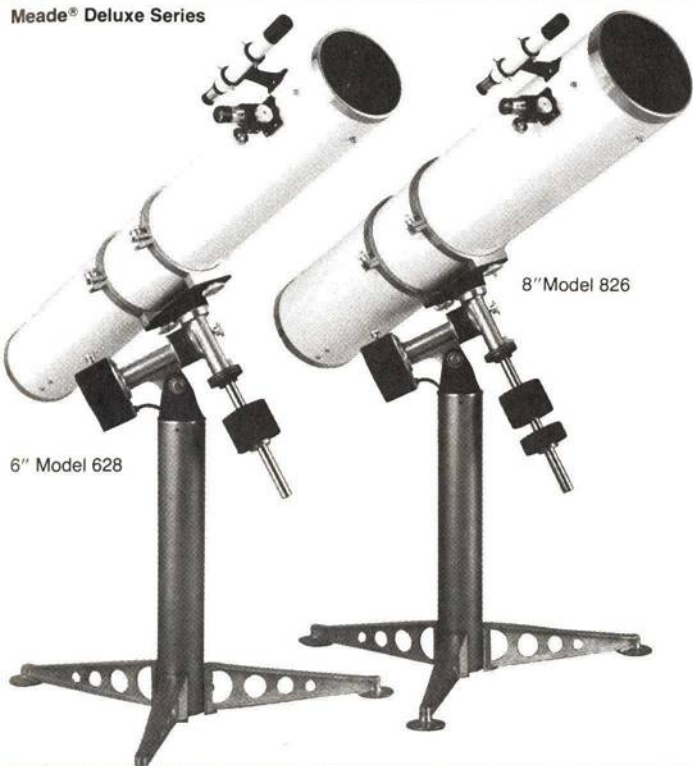
with a locking cable release and turn on the flood lights to make the red exposure. A darkroom timer on the lights is helpful to control the length of the exposure. When the red exposure is done, replace the print and filter with the green ones and make another exposure. Do the same for the blue filter and print. After you've made all three exposures, close the shutter and turn on the room lights. If your camera can make double exposures, you can use the shutter and aperture controls to do this with the lights on. Once the exposing is done, either process the film yourself or send it out to a commercial processor. (Since this is such a valuable roll, you may want to have a custom lab process it.)

Once you perfect this technique, you will produce stunning, contrasty color images of astronomical subjects more vivid than any others. The tricolor process is a valuable, relatively easy tool for backyard sky photographers. It brings us closer to experiencing the grand beauty of the cosmos.

Jim Baumgardt is an electronics engineer in Los Angeles and has been interested in astronomy for about 4 years. He has built several telescopes ranging from 6-inches' to 12.5-inches' aperture and is an avid astrophotographer.

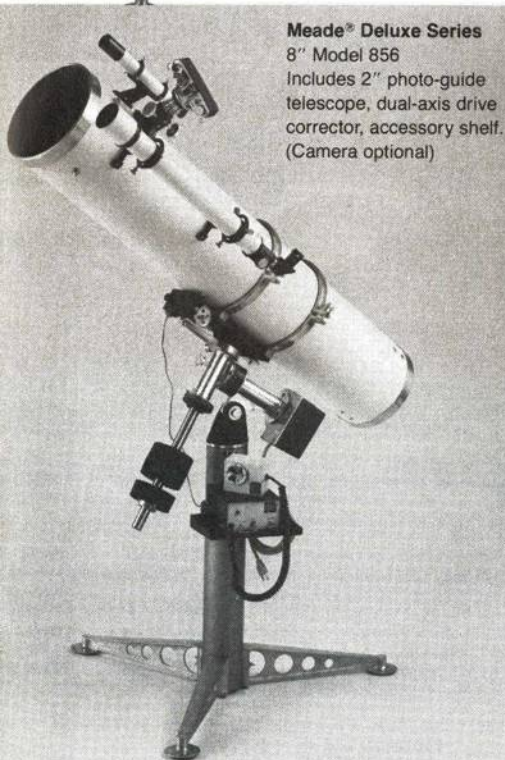
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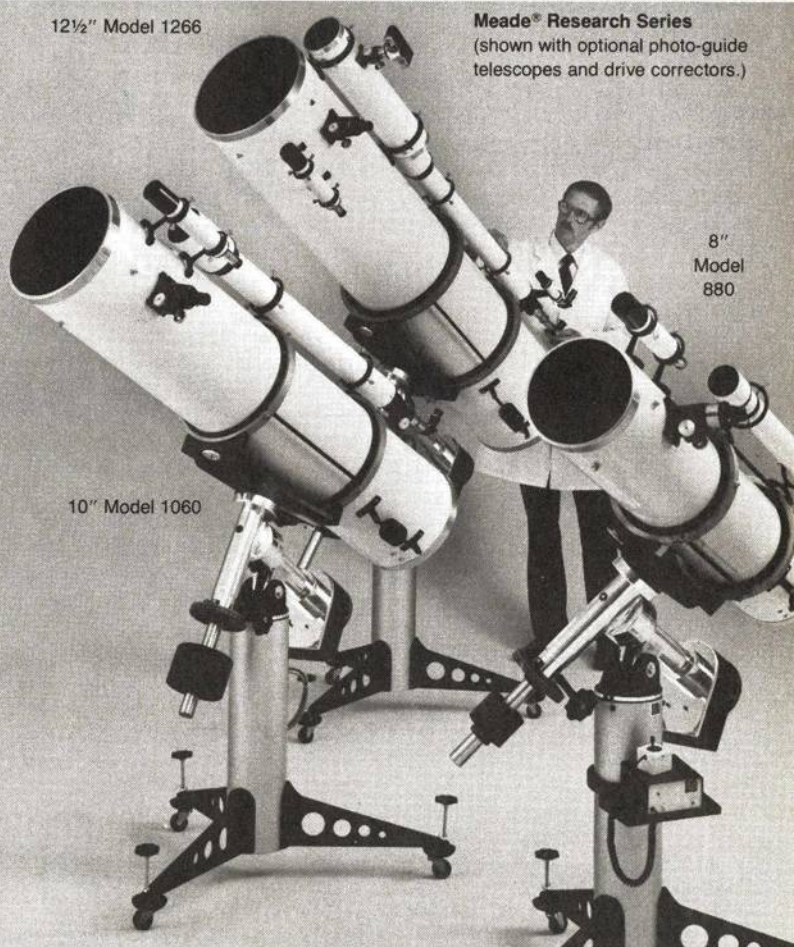
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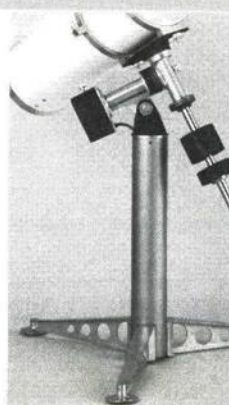
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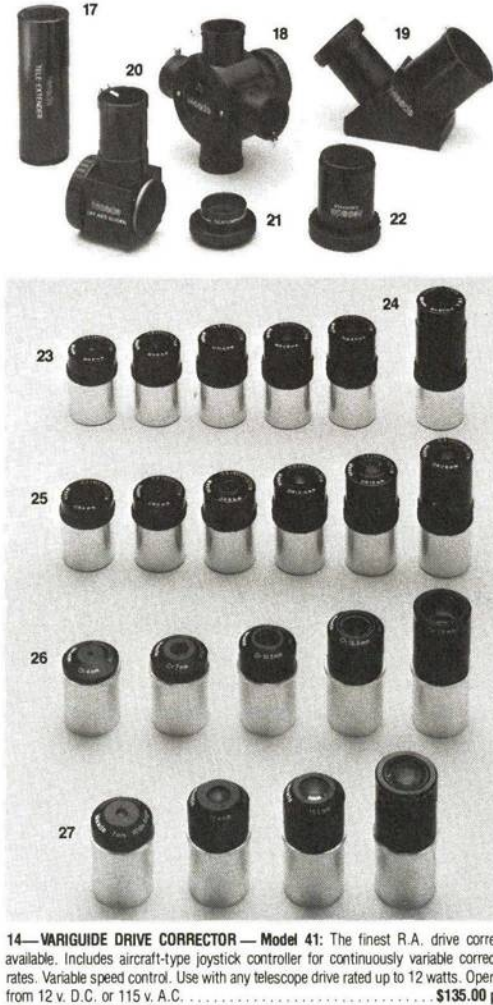
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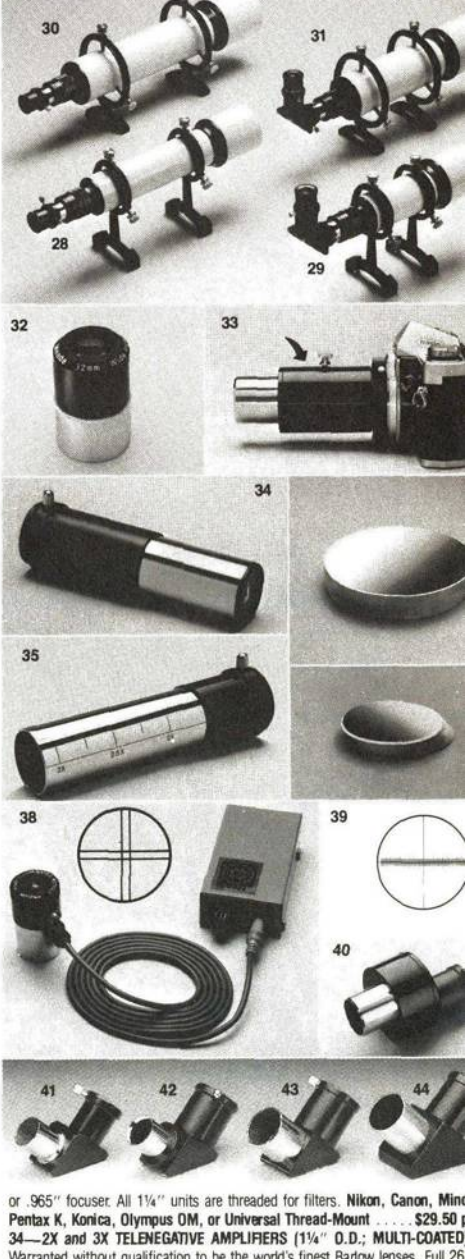
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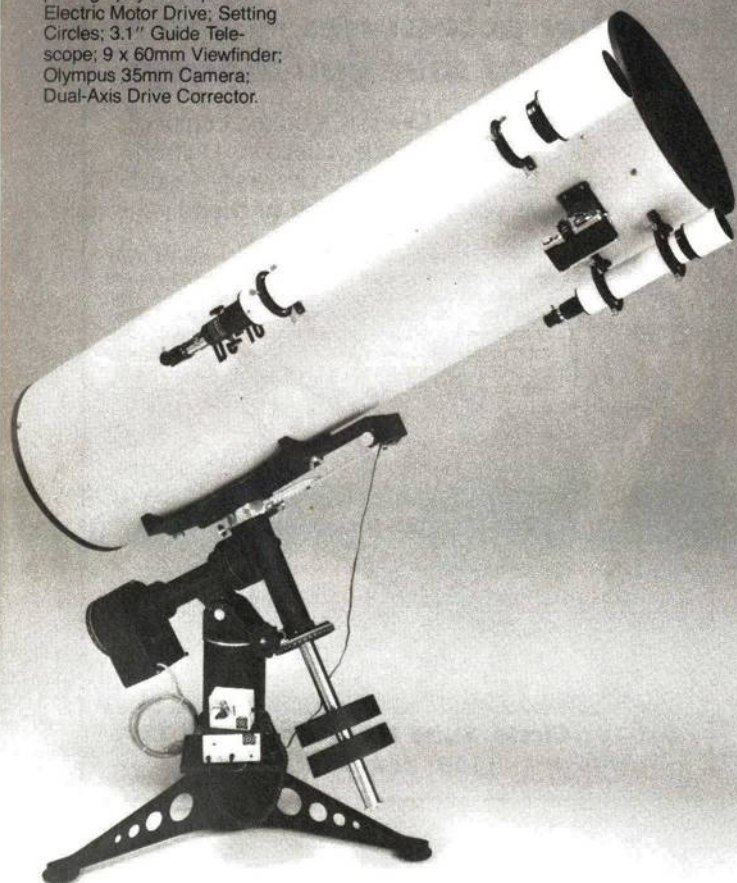
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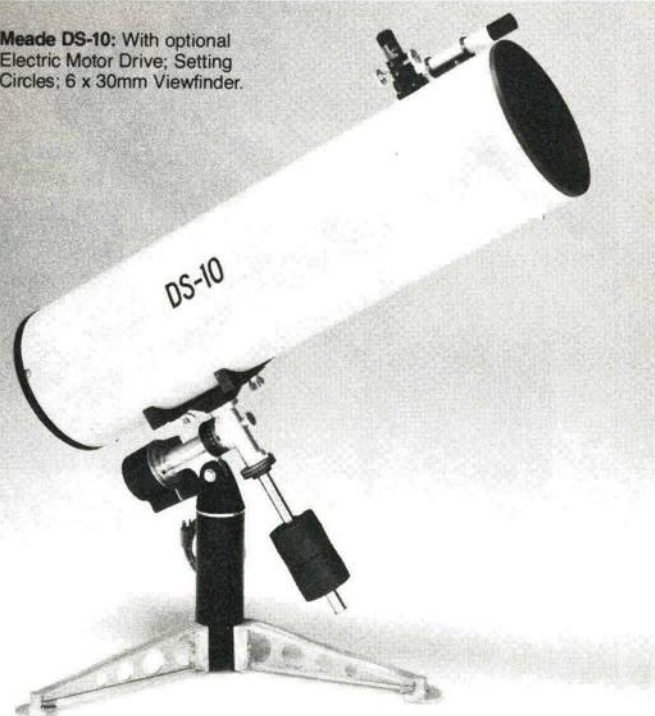
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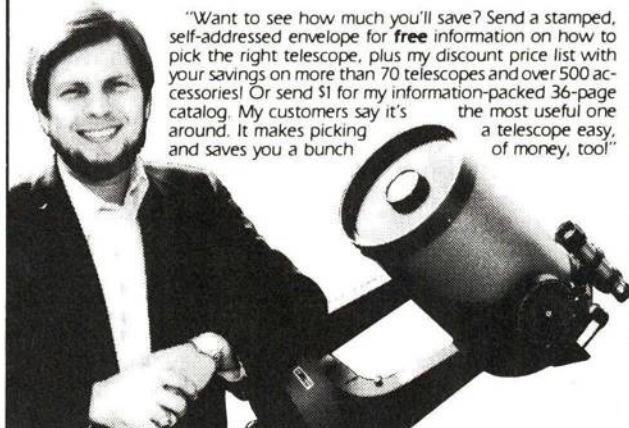
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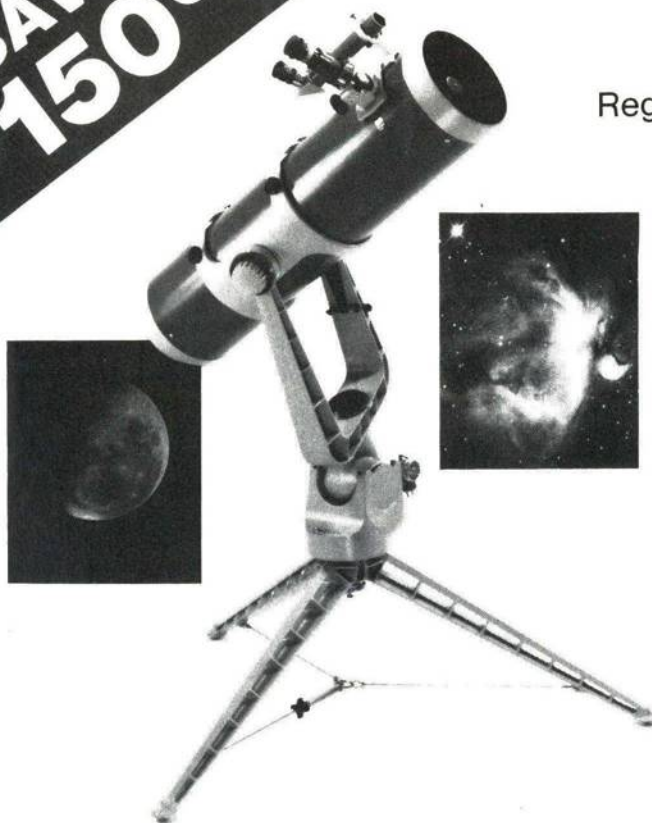
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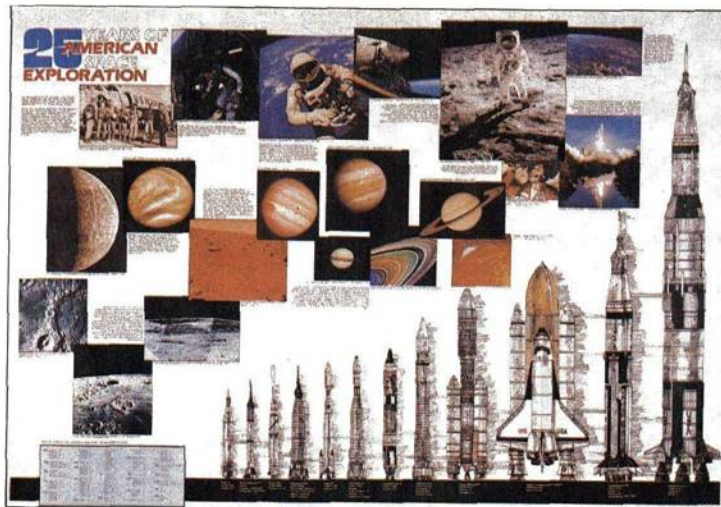
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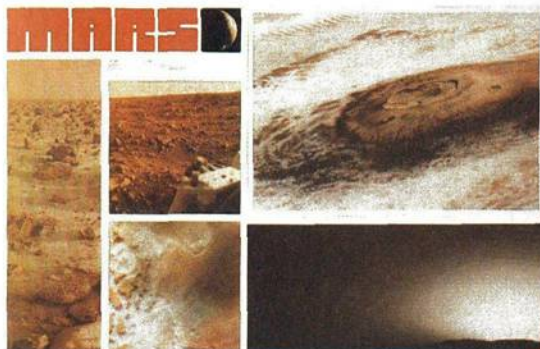
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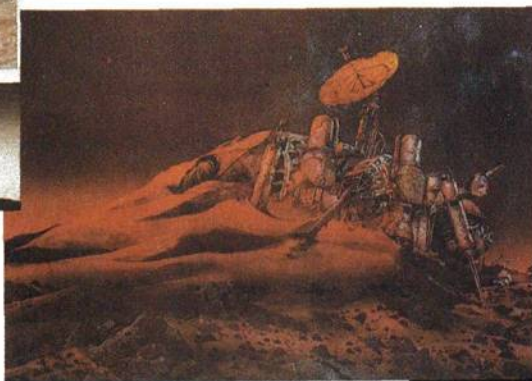


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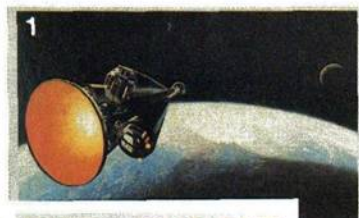
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A Second Solar System?

In early August astronomers using IRAS, the *Infrared Astronomical Satellite*, discovered a shell of dark material orbiting the star Vega (Alpha Lyrae), perhaps indicating the presence of an infant solar system. At the very least, this discovery provides the first conclusive evidence that large solid objects exist around a star other than our Sun.

Working with IRAS at the Rutherford Appleton Laboratory in Chilton, England, astronomers Harmut H. Aumann of the Jet Propulsion Laboratory and Fred Gillett of Kitt Peak National Observatory turned their instrument toward Vega for calibration. They noticed that the magnitude 0.0 star appeared much brighter than they expected in the infrared portion of the spectrum. The two scientists determined that the thermal radiation comes from a region stretching some 80 astronomical units (about 7.4 billion miles) out from the star. (By comparison, our outermost planet, Pluto, lies at an average distance of 40 astronomical units.) IRAS measured the temperature of the material at about

90° K (–300° F) — approximately the temperature of particles found in the innermost rings of Saturn.

According to Gillet and Aumann's hypothesis, the material must be larger than cosmic dust grains because such small particles would have already been drawn into the star by Vega's gravity. The particles are presumably abundant in hydrogen and may be coalescing into planets or small bodies like meteoroids or asteroids.

Scientists believe that our solar system formed some 4.6 billion years ago from debris left over from the Sun's development. Because of Vega's relative youth — the star is less than a billion years old — the material around it cannot have reached the same stage of evolution as our solar system. For the moment, Gillet is decidedly noncommittal: "The particles could range from the size of buckshot to the size of an asteroid or a planet."

Vega is the fifth brightest star in the sky and the brightest in the constellation Lyra. It lies 26 light-years away and is a young ordinary main-sequence star of spectral type A0 V. It is twice as large as the Sun and 60 times as luminous. During the next few weeks and months, IRAS will again look at Vega, attempting to determine whether the heat-emitting cloud is shaped in a ring or sphere.

Companions for Old Stars

Population II is the astronomer's name for the oldest stars in our Galaxy, found in globular clusters and scattered throughout the Milky Way's halo. In contrast to the metal-

rich Population I stars — like the Sun — that reside in the galactic disk, they have little metal content. And while astronomers estimate that about 50 percent of all stars have at least one gravitationally bound stellar companion, the evidence for binarity in old Population II stars seems scant.

According to Virginia Trimble at the University of Maryland, globular clusters show no convincing examples of eclipsing binaries, stars whose brightness fades because a faint companion blocks its light from our view. They also don't seem to harbor spectroscopic binaries, systems in which the gravitational tug of an unseen star creates regular variations in spectral lines. Astronomers have found only a few spectroscopic binaries among the old stars of the galactic halo.

Why this discrepancy? Perhaps binaries never formed back in the Milky Way's early days, in which case the deficiency of paired Pop II stars gives astronomers a clue to how star formation may have changed in the past 10 billion years. Or perhaps the binaries did form, but the star pairs have somehow merged or broken apart — and this gives astronomers information on the dynamical evolution of globular clusters and binary systems.

Although globular clusters contain few, if any, normal binary systems, they harbor 100 times the number of strong X-ray sources and 10 times the number of cataclysmic variable stars found among younger Pop I stars. But the best models of Pop I cataclysmic variables and X-ray sources invoke binary systems in which one of the components is a white dwarf or neutron star!

Several astronomers have concluded that the X-ray objects result from the gravitational capture of a main-sequence star by a solitary neutron star or white dwarf. Recent calculations by Paul Hertz and Jonathan Grindlay of the Harvard-Smithsonian Center for Astrophysics suggest that the globular cluster binaries actually formed by such a "tidal capture" mechanism. All of the X-ray sources and cataclysmic binary systems found in globular clusters are products not of the normal evolution of binary systems, but of main-sequence stars gravitationally captured by single white dwarfs or neutron stars.

Hertz and Grindlay agree that tidal capture should also form pairs of main-sequence and giant stars, but they argue that these binaries will be concentrated in the crowded cores of globular clusters. The density of these regions is so great that the stars

could escape detection as spectroscopic variables or eclipsing binaries.

What does all this mean? Apparently, globular clusters are not born with binary systems in place, a conclusion that any complete model of star formation must eventually explain. Instead of inheriting their binaries, globulars create them late in life through gravitational capture.

Pulsars in Coalescence

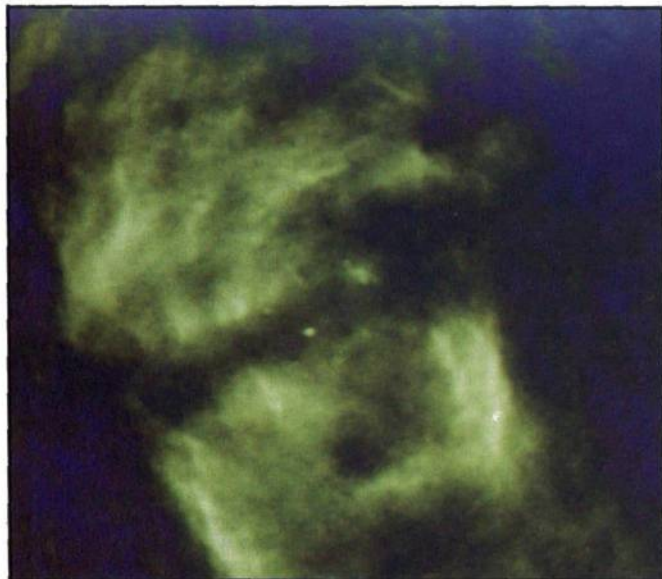
Probably the most dramatic astronomical discovery so far this decade — judging by the number of papers published on it — is the discovery, announced late last year in *Nature* and reported in the March 1983 issue of *ASTRONOMY*, that radio source 4C21.53 (since renamed PSR 1937+214) is in fact a pulsar.

Finding a new pulsar is not particularly unusual — nearly 400 are now known. What makes this new discovery exciting is the extremely unusual nature of this particular pulsar. PSR 1937+214 rotates 642 times each second — once every 1.5578 milliseconds. David J. Helfand of Columbia University has calculated that the pulsar's equator is moving at nearly a fifth the speed of light; if it were moving much faster, centrifugal force would tear the star apart. The energy of this incredibly rapid rotation rate is enough to power an entire supernova!

This evidence suggests that 1937+214 is a very young pulsar. But the catch is that there is no detectable supernova remnant associated with the pulsar. Furthermore, the object's relatively weak (for a pulsar) magnetic field and the consequent slow braking of its rotation speed both suggest that it is an old pulsar.

The consensus among astrophysicists for resolving this contradiction has been that 1937+214 is an old pulsar that has somehow been sped up. The easiest way to explain the increase in speed is to assume that matter has fallen onto the pulsar. This would speed up its rotation in much the same way that an ice skater can increase his spin by pulling in his arms. And the easiest way to find matter that might fall onto the pulsar is to invoke a companion star orbiting it nearby and shedding its outer atmosphere. However, astronomers are almost certain that 1937+214 is currently single; so theorists must find a reasonable way to get rid of the secondary star.

S106 is a region of ionized hydrogen in Cygnus about 2,000 light-years distant. This VLA image reveals the nebula's curious structure: two jets of gas flow outward on either side of an un-ionized patch. This dark band appears to be a thick disk of gas and dust, and within it lies the star that powers the nebula (seen as the bright point, center). Courtesy John Bally.



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Recently, H.F. Henrichs and E.P.J. van den Heuvel of the University of Amsterdam, writing in *Nature*, have suggested a new mechanism that might serve to speed up the pulsar, yet which doesn't violate the few facts we know about the star.

First, they discuss why they think some of the other models proposed will not work. For example, suppose the system starts with two very massive stars, one of which goes supernova without disrupting the system. This leaves us with a neutron star and a massive companion. Before it evolves to the stage where it, too, blows up, the massive star will deposit matter onto the neutron star, thereby increasing its spin. When the massive companion evolves and finally explodes, the system breaks apart, leaving two neutron stars rapidly separating from each other. One would have a normal spin; the other, a "pumped up" rate measured in milliseconds.

This model has at least one major flaw. Working from dynamical and astrophysical considerations, the scientists argue that since at least half the mass of a system must be ejected explosively to break it apart, the companion star must have weighed, at minimum, some 4.2 solar masses before it exploded. And since this represents what survived the supernova of the primary, the original mass for the companion star must have been far higher — probably somewhere around 15 solar masses. This in turn poses a great difficulty in that so large a star would evolve into a supernova much too quickly to transfer enough mass to spin up the pulsar to the observed rate.

Next, let's suppose that after the first supernova detonates, we are left with a neutron star and a red giant of four to eight solar masses. The red giant's stellar wind will steadily dump material onto the neutron star, causing it to speed up. But this model also has its problems: assuming the most favorable conditions, the authors calculate that the neutron star can capture at most $\frac{1}{20}$ the mass required to account for its present spin.

Now suppose the neutron star's companion is a small, low-mass star in a very close orbit. A number of these systems are believed to exist in the Galaxy's central bulge and in its globular clusters. However, the authors argue that in such a system the low-mass star would tend to spiral out rather than in, which would soon halt any mass transfer. And, in any case, small stars can't go supernova and disrupt the system — thus leaving us with the original

problem of getting rid of the companion star.

Finally, the scientists turn to their own hypothesis. Imagine two very massive stars that orbit just far enough apart so that when each star goes supernova, the resulting explosion does not have quite enough energy to disrupt the system. We will be left with two co-rotating neutron stars. A number of examples of such systems are known.

But our story does not end here. General relativity predicts that such a system will emit gravitational radiation — and, indeed, one of the latest tests of that theory is the observation that the orbits of such double neutron stars decay at just the predicted rate. As the system radiates gravitational waves, the stars will edge closer and closer to each other.

The orbits will continue to decay until the two stars hurtle around a common center of mass with a period of about one millisecond. Tidal forces will then rip matter off the smaller star and transfer it to the larger one. When the secondary loses so much mass that it can no longer remain a neutron star, the electrostatic forces that support ordinary matter once again reassert themselves, and the star's volume suddenly increases. This feeds more material onto the primary star, adding to its mass and speeding its rotation. Abruptly, the secondary will be torn apart completely.

The authors believe that the surviving neutron star will be left with a rotation period of about one millisecond. Gravitational radiation will slow this down to about 1.5 milliseconds, below which "a neutron star is expected to be unstable to the radiation of gravitational waves." In effect, the slowing due to gravitational radiation should "turn off" at about 1.5 milliseconds — just the value measured for PSR 1937+214.

Noting that we know of systems where "such a process is inevitable," and calculating that "such a process is expected to occur sufficiently frequently in the Galaxy to provide a sizeable formation rate," the scientists conclude that "the presence of one such object within three to five kiloparsecs of the Sun is not surprising." Donald F. Robertson.

Supernova Observed in M-83

On July 3.5 UT, Rev. Robert Evans of New South Wales, Australia, visually discovered a bright supernova in the galaxy M-83

(NGC-5236) in Hydra. This is the fifth such exploding star found in M-83 this century — the others occurred in 1923, 1950, 1957, and 1968 — and the unprecedented third visual discovery of such an object by Evans. At time of discovery the supernova shone at magnitude 13.0, and within a day it brightened to magnitude 12.5.

Observations made by the International Ultraviolet Explorer satellite suggest that the object was



The 1983 supernova in Sc-type galaxy M-83 (indicated). Martin Spencer took this photo with his 12.5-inch scope on July 30.

a Type I supernova, one that threw off an amount of gas equal to the mass of the Sun with a total kinetic energy of about 10^{44} joules. The supernova's precursor in this case may have been a massive white dwarf or the core of a supergiant star spent of nuclear fuel.

The supernova reached magnitude 11.5 by late July, but faded back to magnitude 13 by late August. It is expected to become anonymously dim before late autumn.

Inside a Bok Globule

In the 1940s, astronomer Bart Bok called attention to compact, spherical dark nebulae that he referred to as "globules." Now named for him, these Bok globules generally contain about 10 solar masses of material and are anywhere from 1,000 to 100,000 astronomical units in diameter. The dark spheres of gas and dust were originally thought to be examples of interstellar

material collapsing to form new stars.

These objects represent the simplest single structures in the dense interstellar medium. Their geometry is regular, and they harbor no strong energy sources — characteristics that make them ideal subjects for comparing observation with theory. In principle, radio and optical observations of a particular cloud can provide a fairly complete portrait of its temperature, size, and mass distribution, enabling theoreticians to refine their ideas about the behavior of a spherical system of particles under mutual gravitation.

Recently, astronomers R.L. Dickman and Dan Clemens of the University of Massachusetts studied an isolated, low-mass Bok globule in detail. Their subject lies in Cassiopeia at a distance estimated to be over 1,800 light-years and seems to have a central condensation.

According to Dickman and Clemens, radio observations revealed a temperature gradient from the edge of the cloud to its core: the surface, exposed to the light of nearby stars, is hotter than the dense, shielded central region. They also analyzed the radio spectral lines of molecules in the cloud. Each molecule emits energy at a characteristic wavelength when it changes its rotational state, but that wavelength can be Doppler-shifted by rapid turbulent motions of the gas. The signals from those molecules moving toward Earth will have slightly shorter wavelengths than the expected signal; those from molecules moving away from us will be slightly longer than the expected signal. The result is a broadening of the molecule's spectral line. The Doppler broadening of a spectral line can be used to estimate turbulence in the gas.

The molecular lines emitted by the Cassiopeia globule are extremely narrow, indicating that turbulent motions in the object occur at velocities much less than the speed of sound in the gas — less than 40%.

Astronomers would like to understand the dynamical state of self-gravitating gaseous spheres like the Cassiopeia globule: Is it expanding, contracting through gravitational attraction, or stable?

Although the importance of turbulence in supporting molecular clouds against collapse is presently a topic of considerable debate in the astronomical community, theoreticians can study an example of subsonic gas flow much more easily than its high-velocity counterparts (like the high-speed outflows

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observed near new stars).

So — what will happen to the globule? Dickman and Clemens argue that it is stable, neither expanding or collapsing, supported against contraction by the thermal pressure of the gas within it. But its fate may depend on its motion relative to the galactic plane. If the cloud heads toward the denser gas of the galactic plane, the higher ambient pressures there may destroy the balance between thermal pressure and self-gravity — the cloud may begin to collapse. Alternatively, the cloud could be assimilated — “swallowed up” — by collision with a larger cloud.

There's also the possibility that the cloud will simply disperse into interstellar space. Evaporation of a globule depends strongly on the temperature of the gas in which it's embedded. If its motion through space takes it out of the galactic plane and into the million-degree gas that makes up the Galaxy's corona, the globule could disperse in just 50 million years. But the cloud's evaporation time would be lengthened greatly if it remains in the cooler (10,000°), denser neutral hydrogen in the galactic plane.

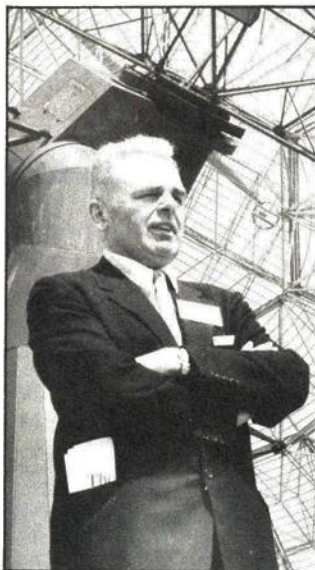


Photo by R. E. Cox

Bart J. Bok 1906-1983

The world lost a great astronomer on August 5 when Bart J. Bok, director emeritus of Steward Observatory and expert on the Milky Way Galaxy, died of an apparent heart attack at his home in Tucson

at age 77.

Born in Hoorn, Holland, in 1906, Bart Jan Bok became interested in the Milky Way as a Boy Scout when he stood watch for hours at night over his fellow patrol members. This childhood interest developed into a serious passion, leading Bok to attend the University of Leiden and then receive his doctorate from the University of Groningen in 1932.

He worked for a short time at the Kapteyn Observatory before moving to Harvard College Observatory in 1929. That same year he married Priscilla Fairfield, an American astronomer. She died in 1975. Bok served as associate director of Harvard Observatory, president of the American Astronomical Society, vice president of the International Astronomical Union, and president of the Astronomical Society of the Pacific. He also directed Mount Stromlo Observatory in Australia starting in 1957, and in 1966 became director of the Steward Observatory of the University of Arizona, located on Kitt Peak.

In 1936 Bart Bok challenged cosmologist Sir James Jeans's estimate of the universe's age at 10 million million years. Dr. Bok's

estimate of less than 20 billion years is still considered a valid estimate today. In 1941, working with his wife Priscilla, Bart Bok authored a popular book about our Galaxy called *The Milky Way*. He recently completed the fifth edition of this work, which has become a classic. Dr. Bok considered astrology an ill-founded idea without scientific value and in 1975 circulated a statement to that effect, which was signed by 186 prominent scientists including 18 Nobel Prize laureates.

Astronomers term a class of dark, compact nebulae “Bok globules” because in the 1940s Dr. Bok pointed out their significance to star formation in the Galaxy. Last April 14 a ceremony at Harvard honored Dr. Bok with a specially inscribed chair. When the carton containing the chair was opened, out came a cloud of black balloons — according to fellow astronomers, the first artificially produced Bok globules.

Dr. Bart Bok was one of the most accomplished and insightful contemporary astronomers. His ability to communicate and hypothesize, as well as deliver a humorous, inspiring speech, was one of a kind.

ASTRO CALENDAR

October 17-20 **15th Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society** (professional meeting). Sheraton Conference Center, Ithaca, New York. For information about travel and accommodations, contact: Joseph A. Burns, Space Sciences Building, Cornell University, Ithaca, NY 14853.

October 21-23 **AAVSO Fall Meeting.** Nantucket, Massachusetts. Host institution, Maria Mitchell Observatory. Contact: Janet A. Mattei, AAVSO, 187 Concord Ave., Cambridge, MA 02138. Phone (617) 354-0484.

October 27-29 **Great Plains Planetarium Association Conference.** Hastings, Nebraska. Contact: Mitch Luman, J.M. McDonald Planetarium, 1330 N. Burlington, Hastings, NE 68910.

October 30 **“The Universe Unfolding,”** nontechnical public lecture series, Stanford University, Palo Alto, California. Sponsored by the Astronomical Society of the Pacific. Contact: Stanford Lectures, A.S.P., 1290 24th Ave., San Francisco, CA 94122.

November 17-19 **IAPPP-Dyer Observatory Symposium,** photoelectric photometry meeting. Host institution, Vanderbilt University. Contact: Douglas S. Hall, Dyer Observatory, Vanderbilt University, Nashville, TN 37235. Phone (615) 373-4897.

January 8-11, 1984 **163rd Meeting of the American Astronomical Society** (professional meeting), Las Vegas, Nevada. Sponsored by the University of Nevada-Las Vegas. Contact: AAS, 1816 Jefferson Pl., N.W., Washington, DC 20036.

August 1984 **6th World General Assembly of International Union of Amateur Astronomers.** Bologna, Italy. Contact: Dr. Luigi Baldinelli, c/o A.A.B., Casella Postale 1630 AD, I-40100 Bologna BO, Italy.

Meeting notices to appear in AstroCalendar must be submitted at least four months in advance of the meeting date. Most organizations appreciate your enclosing a long (business-size) self-addressed, stamped envelope along with your request for information.

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ANNOUNCEMENT — The Boothe Memorial Astronomical Society of Stratford, Connecticut, will have a Halley's Comet Festival in the spring of 1986. The convention will take place in the 18th century town Putney. For more information about this exposition, send SASE to Ron Przybylo, 225 High Park Ave., Stratford, CT 06497.

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ANNOUNCEMENT — The Webb Society is open for membership to amateur or professional astronomers. Quarterly journal. Participate in a worldwide deep-sky organization. Contact Ronald J. Morales, 1440 S. Marmora, Tucson, AZ 85713.

ANNOUNCEMENT — Attention astronomers in South Central Pennsylvania! A new observing group has recently been incorporated. If you would like more information about the organization, send a SASE to The Skywalker Observatory Institute of South Central Pennsylvania, c/o Samuel K. Wenger, Membership Chairman, P.O. Box 997, Lebanon, PA 17042.

ANNOUNCEMENT — The Society of Amateur Radio Astronomers (S.A.R.A.) offers publications, training aids, assistance, and a monthly newsletter to members. For information send long SASE to S.A.R.A., 1548 Bell Flower Court, Stone Mountain, GA 30088.

ANNOUNCEMENT — The newly formed Green Country Astronomical Association meets on the second Monday of each month in Tulsa, Oklahoma. This is an excellent opportunity to guide the organization into the areas of astronomy you enjoy most. Phone Howard W. Malone, (918) 832-7194.

ANNOUNCEMENT — The Timex/Sinclair Computer Club seeks interested individuals nationwide. Exchange programs and send newsletters. Contact Billy Casebeer, Timex Users Group, P.O. Box 372, Oologah, OK 74053.

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WANTED — I am a junior in high school interested in astronomy, theoretical astronomy, astrophysics, planetary studies, or other related fields as career possibilities. I would appreciate hearing from professionals in these fields. Contact J. Miranda, 16731 Brick Road, Granger, IN 46530.

WANTED — ASTRONOMY back issues, September 1973 through December 1973, January 1974, and February 1974. Contact Guenter Lehmann, 720 Park Ln., Hoffman Estates, IL 60195.

WANTED — Correspondence with persons who have taken excellent planetary photographs using apertures of 2" to 18". Contact Gregory Smye-Rumsby, 3 Grasmere Rd., Bromley BR1 4BA, England.

WANTED — Material on the contribution of women to astronomy and space science. Please send biographical material, photographs and/or slides to Dr. Shirley W. Harrison, Department of Physical Sciences, Nassau Community College, Garden City, NY 11530.

WANTED — Information on how to become an astronomer/astronaut (scientist/astronaut), or correspondence with one. Contact Graham MacKenzie, 143 Park St., Sydney, Nova Scotia, B1P 4W7, Canada.

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The Decay of the False Vacuum

by Sten Odenwald

There are four basic forces in Nature — the strong nuclear force, electromagnetism, the weak nuclear force, and gravity, in order of decreasing strength. Physicists since Einstein have sought a single theory that would unite these forces, these interactions with matter, into one comprehensive whole. To do this, scientists have turned to the most powerful high-energy laboratory they know, combining their knowledge of the subatomic realm with their understanding of the present-day cosmos. The early universe, the cosmos just a few moments after Creation, is that laboratory. One of the products of this research is our first glimpse of a unified field theory; another is the new, tantalizing view of our universe only a fraction of a second after the Big Bang.

Gravity and electromagnetism dominate the macrocosm, while both the weak force, which causes the decay of radioactive nuclei, and the strong force, which holds atomic nuclei together, rule the world of subatomic particles. Today, physicists describe any of these forces by using specific groups of particles (called *gauge bosons*) to carry, or “mediate,” each interaction. Photons, for example, carry the electromagnetic force. Whenever photons interact with charged subatomic particles — as when they ionize an atom by striking one of its bound electrons — the electromagnetic force is at work. Each of the four fundamental interactions produces its force through the gauge bosons that carry it. In our example, the gauge boson is the photon, the quantum of electromagnetic energy.

In the 1960s and 70s, physicists developed a theory showing that electromagnetism and the weak force were really different sides of the same coin. This “electroweak” theory, developed by physicists Steven Weinberg and Abdus Salam, has survived every experimental test so far. Its most recent triumph, in fact, was the actual detection of the particles that produce the weak force. Predicted by the Weinberg-Salam theory, these particles are called *intermediate vector bosons*.

When the universe became so cool that these particles collided at energies below 100 billion electron volts, the electroweak theory shows that a curious event took place. The intermediate vector bosons, which had been massless, suddenly gained masses 90 to 100 times greater than that of the proton! (Particle physicists express temperature in terms of collision velocities, so when the universe had cooled to below one trillion degrees, particles in the cosmos collided at energies less than 100 billion electron volts, or 100 GeV.) At higher temperatures, these carriers of the weak force have rest masses of zero, like the photon.

If the average temperature of the universe were now a

trillion degrees, its constituent particles would collide at energies of 100 GeV. The particles that mediate electromagnetism and the weak force — photons and intermediate vector bosons, respectively — would both have rest masses of zero and behave the same way. The two forces would be completely indistinguishable. Although these two fundamental forces gain separate identities at energies below 100 GeV, the Weinberg-Salam theory shows that the electromagnetic and weak interactions act in precisely the same way above this threshold.

Over the last decade physicists have formulated even more powerful theories, frameworks that attempt to unite the weak, electromagnetic, and strong nuclear forces. One of the simplest of these Grand Unification Theories, or GUTs, was developed by physicists Howard Georgi, Helen Quinn, and Steven Weinberg. Called SU(5) (pronounced “ess you five”), it predicts that the strong and electroweak forces will eventually have the same strength when particles collide at energies above 1,000 trillion GeV — an energy corresponding to the unimaginable temperature of 10,000 trillion trillion degrees!

SU(5) requires exactly 24 particles to mediate the three forces it tries to tie together: eight massless particles (called *gluons*) for the strong force, three massless intermediate vector bosons for the weak force, and the massless photon for the electromagnetic force. The remaining 12 particles, called *leptoquark bosons*, represent a totally new class. Physicists believe that quarks are truly fundamental particles; the protons and neutrons with which we are familiar are thought to be made from clusters of three quarks. Leptoquark bosons have the remarkable property of transforming single quarks into electrons. How is this minute transformation significant to the universe? Physicists believe that each proton is constructed from three quarks, and since quarks can now decay into electrons, SU(5) predicts that protons are no longer the stable particles we’ve always imagined them to be. Crude calculations suggest that they may have half-lives between 10^{29} and 10^{33} years. Even if the universe were destined to expand for all eternity, all of its matter would catastrophically decay into electrons, neutrinos, and photons after “only” 10^{33} years. The era of matter, with its stars, galaxies, and living organisms, would be swept away forever, having represented but a fleeting episode in the history of the universe.

In addition to proton decay, SU(5) predicts another new family of particles — *supermassive Higgs bosons* — with masses expected to be around 1 thousand trillion times that of the proton. As it happens, these particles are extremely important for unifying the strong and electroweak forces. In addition, they helped make the universe what it is today.

The GUT Transition

Other Bubbles

Universe cools to below 10^{28} degrees
Particles collide at energies below 10^{15} GeV

° The cosmos we observe — 20 billion light-years across — is a tiny portion of the immense bubble in which it formed.

10^{3000} light-years = Present diameter of our bubble
(Time taken to become this big is 10^{-24} second)

The GUT Era

How do all these ideas relate to the history of the universe? Imagine a time when the average temperature of the universe was not the frigid 3° K that it is today but an incredible 10,000 trillion trillion degrees (10^{15} GeV). According to the standard model of the Big Bang, this was the condition of the universe about 10^{-37} second after Creation. Protons and neutrons didn't yet exist, for the quarks from which they form didn't interact strongly enough to bind together into neutron or proton "packages." The remaining constituents of matter — electrons, muons, and tau leptons — were also massless, essentially traveling at light-speed. The dozen leptons and the supermassive Higgs bosons existed side by side with their anti-particles. Pairs of particles and antiparticles annihilated themselves, but this loss was balanced by the creation of new particle-antiparticle pairs somewhere else in the universe.

During this period, the particles carrying the strong, weak, and electromagnetic forces had rest masses of zero, so these forces were not distinguishable from one another. Any physicist of that age would never have wondered about a similarity between the strong, weak, and electromagnetic interactions — this union would have been directly observable. Furthermore, there were far fewer particles for such scientists to keep track of. Strange as it may sound, the universe at 10^{15} GeV would actually have been much simpler than the cosmos of today!

But as the universe cooled below this temperature, the strong nuclear force suddenly gained an identity separate from that of the electroweak interaction. Nobody knows exactly what happened to the universe when the forces of Nature became distinguishable in the two transitions at 10^{15} and 100 GeV. Physicists are still investigating the early universe, and some groups have offered tantalizing descriptions.

Most people would describe a vacuum as a complete void, a box containing absolutely nothing. In truth, all vacuums contain particles and radiation — especially the vacuum of the early universe. Physicists define a vacuum as the lowest energy state available to any collection of particles. But something interesting happened to the universe as it cooled to energies below 10^{15} GeV, and again as it became cooler than 100 GeV.

Let's examine the 100 GeV transition, the one that gave the weak and electromagnetic forces separate identities. According to the Weinberg-Salam model, the vacuum actually had two "lowest energy" states, one with a higher minimum energy than the other. The culprit behind this situation is called the *Higgs boson*. In the vacuum's high-energy ("hot") state, the Higgs particle has a rest mass of zero and behaves

like a photon — electromagnetism and the weak nuclear force are identical. But Higgs bosons in the low-energy ("cold") phase actually have mass. The massless intermediate vector bosons absorb these massive Higgs particles, becoming massive themselves. Now that the intermediate vector bosons behave differently than photons, which are massless, electromagnetism and the weak nuclear forces become distinguishable.

A similar process occurred earlier as the universe cooled to 10^{15} GeV in the GUT transition. In this case, though, much more massive versions of the Higgs particle were needed. So the SU(5) model of the GUT transition predicts the existence of supermassive Higgs bosons. Between 1979 and 1981, physicists Alan Guth, Steven Weinberg, and Frank Wilczek argued that the GUT transition, which separated the strong and electroweak forces, may have happened in somewhat the same manner as vapor bubbles form in a pot of boiling water. In this analogy, the inside of the bubbles represents the vacuum state of the new, cooler, low-energy phase, where the strong and electroweak forces exist separately. These "bubbles of asymmetry" were embedded in the old, hotter, high-energy phase of the universe, where the forces remained identical. The phase we live in has four separate forces; this has been called the "true" vacuum state. In the false vacuum state, all of these forces remained unified and indistinguishable — certainly not the situation in which we find ourselves today.

Cosmic Inflation?

An exciting prediction of this bubble model is that the universe may have undergone at least one period when its expansion was far more rapid than that predicted by the standard view of the Big Bang. The minimum energy "ground state" of the false vacuum (before the GUT transition) was much higher than the minimum energy state of the true vacuum (after the transition). As the universe cooled, more and more bubbles of true vacuum appeared. But the false vacuum state had a higher minimum energy than the new, cooler phase, and this residual energy caused the universe to expand at a rate much greater than that suggested by the standard Big Bang model. The universe would have inflated at a tremendous rate, expanding exponentially with time, instead of the linear rate predicted by the Big Bang model. The difference between linear (1, 2, 3, 4, 5, . . .) and exponential (1, 2, 4, 16, 256, . . .) rates of expansion is enormous. This exponential expansion ended only when the true vacuum had completely supplanted the false vacuum of the old, hot phase of symmetry.

A major problem with Guth's original bubble proposal was that the universe's inflationary phase would never have

Nature's Four Interactions

Force	Relative Strength	Particles Exchanged	Particles Acted Upon	Range	Example
Strong	1.0	Gluons	Quarks	10^{-13} to 10^{-14} cm	Binds atomic nuclei together
Electromagnetic	$\frac{1}{137}$	Photons	Electrically Charged Particles	Infinite	Photo-ionization of neutral atoms
Weak	$\frac{1}{10,000}$	Intermediate Vector Bosons	Protons, Neutrons, Electrons, Neutrinos, etc.	Much less than 10^{-14} cm	Beta decay of radioactive nuclei
Gravity	6×10^{-39}	Gravitons	Everything	Infinite	Holds planets in orbit around Sun

ended. The universe becomes trapped in a cul-de-sac and its exponential expansion never ceases. This is somewhat analogous to water refusing to freeze even though its temperature has dropped well below its freezing point. Today's model of the "inflationary universe" was developed by A. Lind in the Soviet Union, Andreas Albrecht and Paul Steinhardt in the U.S., and Britain's Stephen Hawking. It allows the universe to escape from the false vacuum and evolve in a short time to the true vacuum that we live in today.

We don't know exactly how long the inflationary phase lasted, but the time required for the universe to double its size may have been only 10^{-34} second. Conceivably, this inflationary period could have continued for as long as 10^{-24} second, during which time the universe would have undergone 10 billion doublings of its size. As a comparison, a hydrogen atom would need only 120 doublings to inflate to the size of the entire visible universe!

According to the old inflationary model, the bubbles of the true vacuum phase expanded at the speed of light. In order to form a universe as smooth as the one we observe, many of these bubbles had to collide when the universe was very young. According to the old model, a single bubble could not grow large enough to encompass the entire visible universe, about 20 billion light-years across. But according to the revised inflationary model, even the bubbles expanded exponentially in size — that is, the bubbles expanded just as rapidly as the space between bubbles. In the new model, the bubbles themselves became truly enormous, growing to sizes much larger than the observable universe. According to Soviet physicist A. Lind, each bubble may now be 10^{3000} light-years across.

In reality, the bubbles didn't actually expand. After all, such enormous growth taking place in a fraction of a second requires velocities far greater than the speed of light. Think about each bubble this way: a region of space now about 10^{3000} light-years across that just happened to undergo the transition almost simultaneously. Nothing spreads the transition throughout that space — it's just that a lot of tiny areas went through the transition at nearly the same time. All those individual sections add up to a bubble 10^{3000} light-years across.

GUMs from GUTs

Phase transitions during the GUT Era could spawn a curious zoo of particles if bubbles frequently merged. Such mergers were required by the inflationary model of Guth, Weinberg, and Wilczek. Physicists can view the universe as a collection of particles and their associated fields. Photons create an electromagnetic field, the particles that mediate gravity (called *gravitons*) create a gravitational field, and so

on. Each bubble of true vacuum contained a field generated by the massive Higgs particles that appeared within it, and each of these Higgs fields had a unique orientation in space. It seems likely that no two bubbles would have their Higgs fields oriented in quite the same way, so knots should have formed when the bubbles merged. According to Netherlands physicist Gerard 't Hooft and Alexander Polyakov in the Soviet Union, these knots are the magnetic monopoles originally proposed 40 years ago — massive particles that carry magnetism just as electrons carry electrical charge.

There should be as many of these Grand Unification Monopoles (GUMs) in the observable universe as there were bubble mergers in this region during the transition period. The bubbles in the old inflationary model were very small, and many of them had to merge to make a universe with any resemblance to the one astronomers now observe. A lot of bubble mergers in the space that now makes up our observable universe means that there should be a great number of monopoles. Calculations based on this model gave scientists estimates of the maximum number of these particles and their mass. The result: For every 10 billion photons in the microwave background radiation, there must be one very massive magnetic monopole. But this answer *couldn't* be correct — so many massive monopoles would have halted and reversed the expansion of the universe in just a few thousand years!

The new model solves the problem of monopole overproduction. The universe we see is only part of one enormous bubble, not a conglomeration of several merged bubbles. Few, if any, bubble mergers occurred in our part of the cosmos, so there should be very few monopoles in the observable universe. Calculations indicate that monopoles must be at least 1 trillion trillion times less abundant than the microwave photons in the cosmic background noise.

Horizons

A prolonged period of inflation would have had an important influence on the background radiation from the cosmic fireball. All directions in the sky show the same 3° K background temperature to an astonishing 1 part in 10,000. Regions separated by only a few degrees in the sky are actually very far apart — light, microwaves, or any other energy could have completed the trip between two such regions only very recently on the cosmic timescale. It's hard to understand how regions in the sky even farther apart could have such a remarkably similar temperature. Even if the radiation from one region started on its way, traveling at the speed of light, when the universe came into existence, it could not have traversed the intervening distance to the other region. This "communication gap" would prevent the

universe from ironing-out temperature differences between greatly separated areas. How do cosmologists get around this?

Let's consider a particle's view of the universe. As we look further back in time, the amount of the universe visible to the particle shrinks. That is, the closer we are to the Bang, the less time there was for a particle to detect light from distant areas — its "light horizon" becomes smaller as we look back in time. Eventually, as we look back to very ancient times, the light horizons around each particle are so small that every particle in existence fills the entire volume of its own observable universe. Imagine a universe where you occupy all of the available space! Prior to the development of the inflationary models, cosmologists were forced to imagine an incredibly well-ordered initial state where each of these disconnected domains (some 10^{83} of them!) had nearly identical properties, like temperature. Any departure from this situation way back then would have grown to detectable temperature differences in widely separated parts of today's sky. Unfortunately, this scheme requires some agent to set up the finely tuned initial conditions. And this violates causality since no force may operate by transmitting its influence faster than the speed of light.

The inflationary universe eliminates this contradiction. Let's look back at the GUT transition. A region of space that is now 10^{3000} light-years across was very small then. The radiation throughout that area was precisely the same temperature when inflation occurred. Our horizon, our observable universe, is only 20 billion light-years across. Since our observable universe is much, much smaller than the size of our bubble, the background radiation we see has exactly the same temperature.

Instant Flat Space

The universe grew exponentially during the GUT Era, increasing its size enormously in a very short amount of time. Estimates of bubble size suggest that each one may have grown to a diameter of 10^{3000} light-years by the end of the inflationary period — for all practical purposes, our bubble is infinite in size since we see so little of it. The universe is, for all conceivable observations, exactly Euclidean (infinite in extent, flat in geometry) and destined to expand for all eternity. Of course, the idea of an essentially infinite, ever expanding universe raises a ghastly spectre — the eventual annihilation of all matter some 10^{30} years from now because of proton decay.

In spite of its many apparent successes, this new view of the universe still has problems. Although it does seem to provide explanations for several cosmological enigmas, it doesn't yet provide a convincing way to create galaxies. Any fluctuations in the density of matter able to survive the

inflationary period have to be so dense that they eventually collapse into galaxy-sized black holes! In addition, the duration of the inflationary period is not well determined, and no one understands how the universe switched to the uniform expansion we presently observe.

If inflationary cosmologies can solve these problems, we have a most remarkable model of the universe: An essentially infinite number of huge "bubble universes" co-existing in the same four-dimensional spacetime. All of these bubble universes came into existence at the same instant. It's even conceivable that the universe is "percolating," with new bubble universes continually popping into existence. Our entire visible universe, out to the most distant quasar, is but one infinitesimal patch within one of these bubble regions. Do the other universes have galaxies, stars, planets, and living creatures? Are they similar to those in our universe? We may never know. These other universes, born at the same time as our own, are forever beyond our scrutiny — but not our imaginations!

Beyond the Beginning . . .

Finally, what of the period before the Grand Unification era? At temperatures higher than those in the GUT Era, even the supermassive Higgs and leptoquark bosons may become massless particles. At long last, we arrive at a time when the gravitational interaction unites with the weak, electromagnetic, and strong forces. But our quests for a truly unified field theory and an understanding of the origins of the universe remain uncompleted — gravity has yet to be unified with the other fundamental forces on a theoretical basis. This last step is not only the most difficult one, but also appears to hold the greatest promise for elucidating some of the most profound mysteries of the physical world. Even now, theorists around the world are hard at work on a theory called *Supergravity*, which unites all of the particles that mediate interactions (photons, gluons, gravitons, and the bosons of the weak interaction) with the particles that they act upon (quarks, electrons, etc).

Over the next decade, physicists will hammer out more of the details of this last stage of unification. Perhaps then the entire story of the birth of our universe can be told. This is, indeed, an exciting time in human history. Future generations may forever envy us our good fortune: to have witnessed in our lifetimes the unfolding of the first comprehensive theory of Creation.

Sten Odenwald, an infrared astronomer, currently works at the Naval Research Laboratory. His research interests include studies of the far-infrared properties of giant molecular clouds and young star forming regions in the Galaxy.

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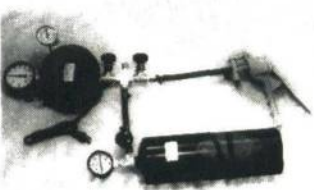
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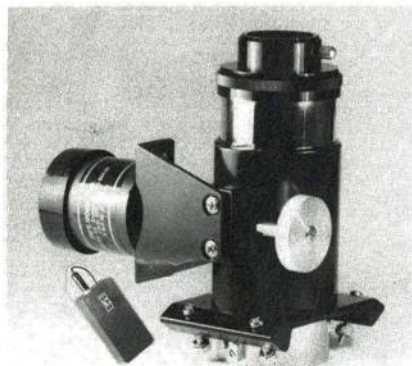
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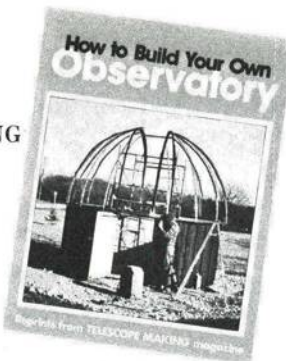
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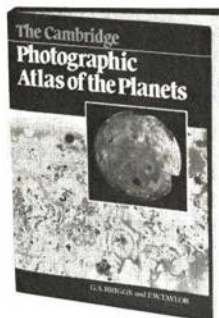
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studying galactic structure with binoculars, part 2

gazer's
gazette

by
Craig Crossen

By November, the Milky Way constellations following Cepheus — Cassiopeia and Perseus — ascend high overhead. The first thing you will notice, if you compare, is that the Milky Way in Perseus is much thinner and fainter than the Milky Way in Cassiopeia. A scan with binoculars shows that except for the region of the glorious Double Cluster, the star fields of Perseus are much poorer than those of Cassiopeia. The reason is that toward Perseus the interstellar gas and dust in our own spiral arm are especially thick, but toward Cassiopeia there is a "window" through our arm — a gap between the dust clouds of Cepheus and Perseus — through which we see the next spiral feature outward from ours.

To get a better galactic perspective on this, look up toward Deneb and the approximate direction of galactic longitude 90° , with — as before — the direction of the galactic center (Sagittarius-Scorpius) on your left and the direction of the galactic anticenter (Auriga-Gemini) on your right. Cassiopeia will be somewhat to the right of 90° , about a third of the way from 90° back toward the galactic anticenter. Thus, when we look toward Cassiopeia, we're looking a little off the direction of galactic rotation, at an angle that would take us away from the interior of the Galaxy and out toward the Galaxy's rim. Toward Cassiopeia we are looking ahead and — because we are on the inner edge of our arm — into our own spiral arm. But since there is a "window" in the interstellar matter of our arm toward Cassiopeia, in that direction we also look through our own arm, past the foreground stars that form the traditional constellation pattern, out at the next spiral feature and toward the galactic rim.

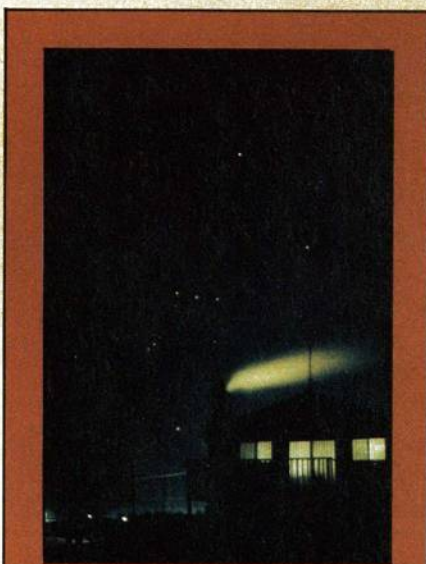
The Cassiopeia "window" extends from

just east of the famous variable Delta (δ) Cephei through Cassiopeia to the Perseus Double Cluster. The feature visible to us through this window is called the Perseus Spiral Arm because the Double Cluster, which is one of the Perseus Arm's major sub-units, lies in it. Each cluster of the great pair is the heart of a large and populous stellar association. The Double

including M-103 (about 8,200 light-years away — in 10x binoculars merely a knot of three stars), NGC-663 (9,000 light-years distant — a much better object for binoculars than M-103, rather large, rather rich, with a few dozen resolved, but scattered, stars), and NGC-457 (around 8,200 light-years away). This last is a striking cluster with a score of stars arranged in a tight northwest-southeast ellipse. At the southeast end of the ellipse sparkle two bright stars; one is the fifth-magnitude Phi (ϕ) Cassiopeiae, a true member of the cluster with an absolute magnitude of $-8\frac{1}{2}$.

Because of our clear view to the rich Perseus Spiral Arm in that direction, Cassiopeia is abundant in open clusters and associations. Perseus itself, at least outside of the Double Cluster region, is much poorer in such objects — the thick interstellar gas and dust blocks the distant objects. There are, however, two nearby associations visible in Perseus; both are excellent groups to examine in binoculars. The closer is the Alpha (α) Persei Moving Group, which includes Alpha (about 570 light-years away), most of the stars in the bright, scattered cluster around Alpha (a fine sight in binoculars), and possibly also the third-magnitude Delta (δ) and Epsilon (ϵ) Persei (two ice-blue B stars 590 and 680 light-years distant, respectively).

In southern Perseus, centered about 8° due north of the Pleiades, is the Zeta (ζ) Persei Association, including Zeta, a B1 Ib supergiant about 1,200 light-years away, and Xi (ξ), which is some 1,600 light-years distant. Illuminated by Xi, and just north of it, lies NGC-1499, the California Nebula. When sky conditions are excellent, this nebula is just visible in 10 x 50 binoculars. These two Perseus associations are only about 30° from the galactic anticenter, so when we look at them from our vantage point on the inner edge of our spiral arm, we are looking back into the core of our arm. However, the view back into our arm is best in the evenings of late winter and early spring, when the galactic anticenter stands high



When Orion's bright stars shine in the sky, it's time to explore the winter Milky Way. Photograph by Carle Turek.

Cluster does not seem to be a physically connected double, but simply a pair of clusters that happens to lie in the same line of sight. The western cluster, NGC-869, is about 7,000 light-years away; its mate, NGC-884, some 8,100 light-years distant.

Embedded in the Perseus Arm are most of the major open clusters in Cassiopeia,

Part 1 of "Studying Galactic Structure with Binoculars" appeared in the July 1983 ASTRONOMY



Above: Nearly opposite the galactic center, the stars of Auriga are the foreground to a multitude of galactic clusters lying in the Perseus Arm of our Galaxy. Photograph by George Briggs.

Right: Lost in a rich stratum of background stars, Cassiopeia overlays dark rifts of interstellar material. Far beyond the arms of our Galaxy, but not far from its plane, lies another spiral, the Andromeda Galaxy, easily visible to the naked eye. Photograph by Steve Reed.



in the western sky.

The Winter Milky Way

Around midnight in winter, the Milky Way is a great arch in the west. It sweeps up out of the horizon haze in the north (where observers in the extreme northern United States and Canada can see Deneb at the lowest of its circumpolar "orbit") from Cepheus up through Cassiopeia and Perseus in the northwest and high into Auriga; from there it descends between Gemini and Orion, down through Monoceros, over the back of Canis Major in the southwest, and finally into the spaces of Puppis, where it is lost to view in the thickness over the southern horizon.

The Milky Way of winter looks different from the late summer/early autumn Milky Way: it is a uniform glow lacking the bright star clouds and obscuring features

like the Great Rift. In part, this is because when we look at the early spring Milky Way we are looking outward toward the rim of the Galaxy, away from the dust and star-rich interior. The galactic anticenter is high in the west, located $3\frac{1}{2}^\circ$ due east of El Nath (Beta [β] Tauri), almost exactly on the Taurus-Auriga border. If you stand facing west, looking up at the position of the galactic anticenter, galactic longitude 90° will be on your right and just about at the north point of the horizon; galactic longitude 270° , the direction from which the Sun has revolved, will be on your left and just about due south at the horizon.

Of course, the precise locations of longitudes 90° and 270° with respect to the horizon will depend on your latitude and the time of evening; but for observers in most of the United States and in

southern Canada, this will prove a useful way to keep these locations in mind while studying the Milky Way at this time of year.

If you straighten your arm and point toward the vicinity of El Nath and the direction of the galactic anticenter and then sweep the arm along the Milky Way toward the north, it will be sweeping in the direction of galactic rotation.

Since we are on the inner edge of our Galaxy's spiral arm, we must be looking back into its core when we look at the winter/early spring Milky Way. This is confirmed by the presence of many relatively nearby open clusters, associations, and bright nebulae in the constellations from Perseus to Canis Major. Beginning in the northwest, in Perseus, are the Alpha Persei Moving



Group, 570 light-years away, and the Zeta Persei Association, centered about 1,200 light-years distant; to the west-northwest in Taurus are the Pleiades, 410 light-years away, and the Hyades, centered at about 150 light-years; to the west-southwest is the mighty Orion Association (after which our spiral arm is named). This group includes Rigel and the stars and nebulosity in the Belt and Sword. It extends from roughly 900 light-years (Rigel) to 2,000 light-years (Kappa [x] Orionis).

In the southwestern sky we see the Canis Major Association, whose brightest members are a splendid color-contrast group in binoculars. Delta (δ) Canis Majoris (2,500 light-years away) is a yellowish supergiant. Eta (η ; 2,400 light-years distant) and Omicron² (σ^2 ; 3,100 light-years) are blue-white supergiants

each intrinsically as bright as Rigel. Omicron¹ (σ^1) is chrome-orange, and Sigma (σ) ruddy. All of the clusters and associations just mentioned except the Alpha Persei Moving Group are well below the bright stream of the Milky Way proper. As you look at the arch of the early spring Milky Way, the Zeta Persei Association, the Pleiades and Hyades, and the Orion and Canis Major associations seem to dangle from it — the effect is quite beautiful.

This arrangement of the nearby clusters and associations back in our spiral arm might be the result of the Sun's being located in the arm a little off the actual plane of the Galaxy's spiral disk. If we looked at our Galaxy edge-on, we might see the Sun a little off the central line of the Galaxy's edge-on profile: this would

mean that we have to look "down" as well as "back" into our arm to see the nearby open clusters, associations, and dust clouds. However, the intriguing distribution of these objects may also result from a local irregularity in our arm — which is, after all, almost 1,000 light-years thick. In any case, it produces an interesting sight.

So in looking at the spring Milky Way itself, we look over and beyond foreground clusters and associations, far back into the core of our own spiral arm. The famous open clusters and nebulae from Auriga into Monoceros are, therefore, "background" objects to the Zeta Persei Association, the Pleiades and Hyades, and the Orion Association.

The Canis Major Association, on the other hand, is centered about 30° from galactic longitude 270°, so when we look toward it we're looking back along the inner edge of our spiral arm rather than back directly into the arm's dense core. When you go up into the Milky Way from the area of the Hyades, Pleiades, and Zeta Persei Association, you are in Auriga and Gemini. M-36, M-37, and M-38 (which range from 4,100 to 4,700 light-years away) in Auriga lie directly "behind" the Hyades, Pleiades, and Zeta Persei Association in our spiral arm.

Over and beyond the Orion Association in the Monoceros Milky Way are the Christmas Tree cluster, NGC-2264, which is about 2,300 light-years away, and the Rosette Nebula, NGC-2237, almost 5,000 light-years distant. The basic "Christmas Tree" outline of NGC-2264 is obvious in binoculars, but the tip of the tree points south. The glow of the Rosette can be easily seen in 10 x 50 binoculars as a very hazy circular patch some 2½ times the Moon's apparent diameter. The half-dozen brightest stars of the central cluster are arranged in a conspicuous northwest-southeast rectangle, but there is no sign of the central "hole" that makes photographs of the Rosette so intriguing.

Very little of the Perseus Spiral Arm can be seen through the interstellar gas and dust of our spiral arm in the stretch of the Milky Way between Perseus and Canis Major. However, beyond our arm — even beyond the Perseus Arm — shines NGC-2158, a very remote but very rich cluster located in Gemini only ½° southwest of M-35.

In binoculars, NGC-2158 is far from impressive — 10 x 50s show only a tiny patch of light — but when you look at it, you are looking at an object around 16,000 light-years away, which means that it is about seven times farther from us than its great neighbor, M-35. NGC-2158 lies in the Outer Spiral Arm of our Galaxy. Since it is only a few degrees from the galactic anticenter, its 16,000 light-year distance implies that it is very near the rim of our Galaxy, shining like a lighthouse beacon at the edge of the blackness of intergalactic space.



the backyard astronomer

pegasus

Mercury

Mercury will be out of sight for just about all of November; greatest eastern elongation occurs on December 13th, and the planet may be just visible very low in the southwest right after sunset on the last few evenings of November. On the 26th, Mercury will pass 3° south of Jupiter, but both will be close to the Sun and the event will be hard to see.

Venus

At greatest western elongation (and highest elevation) on November 4th, Venus is a startlingly prominent object in the eastern sky before sunrise. The planet is very well placed for observations (see *Eye on the Sky*, p. 42), and has enough elevation for you to use medium to high powers on the planet without losing definition due to bad seeing.

Over the weeks that followed inferior conjunction in August, Venus' apparent size has dwindled from nearly a minute of arc across to less than half that: on November 15th, it will be 22" of arc in diameter. It will also become more "Full" after it passes through the half-lit phase on the 4th. By the end of November, it will be distinctly gibbous.

Mars

By sunrise, Mars is well up in the southeast. Though presenting a small disk (about 4.7" of arc across), the planet is still worth observing. High enough to avoid horizon haze, Mars will benefit from a long focal length, high powers, and steady seeing conditions. The planet's northern polar icecap is tipped about 25° toward us and 22° toward the Sun. Aphelion is on November 30th, and the summer solstice is in January.

Jim Riffle used a 105mm f/2.4 lens and a #25A red filter to create this portrait of Orion and its surrounding region — this month's "Best Astro-Photo" winner. He guided by piggybacking his camera atop a telescope and exposed for 15 minutes. Barnard's Loop is conspicuous through Orion; at left is the Rosette Nebula.

Asteroids

1 Ceres (magnitude 8.6) is moving northeastward across the Piscis Austrinus-Capricornus border. Its positions:

9th: 21h 34m 46s, -26° 03.5'

19th: 21h 42m 30s, -24° 58.1'

Ceres sets around 10:30 p.m. local time on the 15th.

2 Pallas (10.5) is transiting the Milky

Juno was at opposition in late October; it is visible practically all night long.

4 Vesta (6.9) lies in eastern Taurus, directly north of Orion. Its positions:

9th: 5h 52m 25s, +18° 01.4'

19th: 5h 46m 25s, +18° 07.5'

Vesta is visible all night long.

To facilitate plotting their positions on a star atlas, all asteroid coordinates are for the epoch 2000.0.

Jupiter

Jupiter vanishes from the evening sky into the glow of light from the Sun this month. How long you can keep it in view depends in part on how much effort you care to take; in any case, by the end of November the Sun will have come close enough to blot it from sight. Conjunction with the Sun is on December 14th.

Saturn

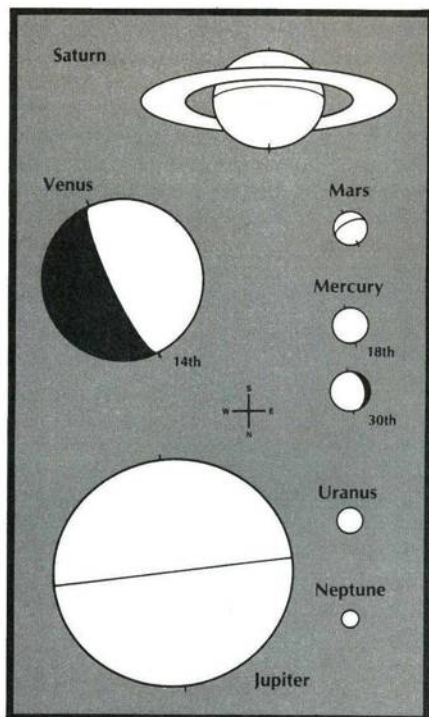
Saturn was in conjunction with the Sun on October 23rd, but will emerge very rapidly from the solar glare into the morning sky. Invisible on the 1st of November, it will be nearly 5° high (45 minutes before sunrise) on the 15th and will reach 16° elevation by the 30th. By next month, its elevation will be sufficiently high to make telescopic observations easy.

Uranus

As with Jupiter, so follows Uranus. Seven degrees high, 45 minutes after sunset on the 1st of November, the planet will be 8° below the horizon at the same time on the 30th. Solar conjunction is December 2nd.

Neptune

This will be your last chance this year to view Neptune. You'll do well to make your observations before the middle of the month — after that time the planet will be very low in the southwest after sunset. Neptune is following hard on the heels of



Way in Aquila from west to east. Its positions:

9th: 19h 05m 02s, +2° 40.6'

19th: 19h 15m 57s, +1° 46.4'

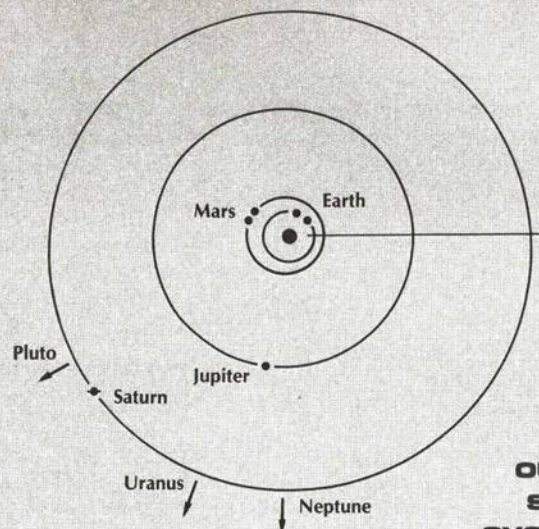
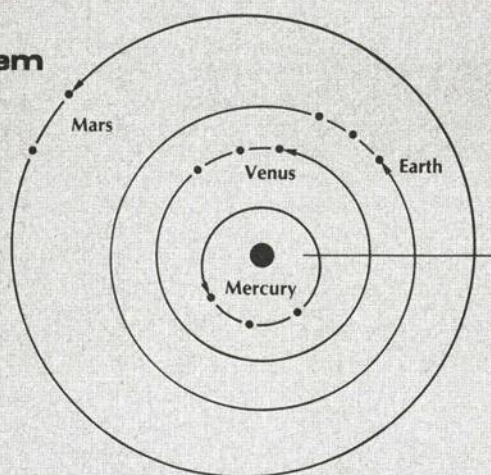
Pallas sets about 9:30 p.m. local time at mid-month.

3 Juno (7.2) is moving southwestward in Cetus. It lies about 10 minutes of right ascension west of 67 Ceti; its positions:

9th: 2h 05m 38s, -6° 18.2'

19th: 2h 00m 39s, -7° 09.8'

For information on naked-eye sky viewing, including planets, constellations, and mythology, see *Eye on the Sky*.

inner
solar
systemouter
solar
system

	Date	Mag.	Angular Size	% Illum.	Distance (AU)		Longitude:		R.A. (1983.9)	Dec.
					from: Earth	from: Sun	Heliocentric	Ecliptic		
Sun	1	-26.8	32.3'	—	0.99	—	—	217°59.9'	14h 22.5m	-14°10.4'
	15	-26.8	32.4'	—	0.99	—	—	232°03.3'	15h 18.5m	-18°16.8'
	30	-26.8	32.5'	—	0.99	—	—	247°12.4'	16h 21.5m	-21°30.8'
Mercury	♿ 1	-0.9	4.7"	100%	1.44	0.44	220°43.2'	218°20.9'	14h 26.1m	-14°10.4'
	15	-0.5	4.7"	97%	1.42	0.47	260°14.8'	240°29.9'	15h 54.2m	-21°33.4'
	30	-0.4	5.3"	88%	1.27	0.43	304°07.6'	263°05.5'	17h 31.5m	-25°34.9'
Venus	♀ 10	-4.0	23.1"	53%	0.73	0.72	94°17.7'	180°09.4'	12h 03.7m	+ 0°42.8'
	30	-3.8	19.2"	63%	0.88	0.72	126°43.3'	201°55.9'	13h 25.9m	- 6°43.5'
Mars	♂ 15	+1.8	4.6"	94%	2.04	1.67	149°12.4'	177°30.0'	11h 54.9m	+ 2°10.3'
Jupiter	♃ 15	-1.3	31.8"	100%	6.20	5.30	259°36.2'	254°54.2'	16h 56.6m	-22°14.7'
Saturn	♄ 15	+0.8	15.5"	100%	10.78	9.82	217°42.9'	218°32.5'	14h 29.3m	-12°25.1'
Uranus	♅ 15	+6.0	3.4"	100%	19.92	18.98	249°09.7'	247°52.8'	16h 26.3m	-21°38.0'
Neptune	♆ 15	+7.8	2.4"	100%	31.06	30.26	268°44.6'	267°13.6'	17h 49.8m	-22°14.8'
Pluto	♇ 15	+13.9	0.1"	100%	30.73	29.85	209°38.2'	209°51.3'	14h 15.8m	+ 3°48.4'

moon data

New Moon.....November 4 at 22:21
 First Quarter.....November 12 at 15:49
 Full Moon.....November 20 at 12:29
 Last Quarter.....November 27 at 10:50
 New Moon.....December 4 at 12:26
 Perigee: Nov. 1 at 2:34.....367,775 km.
 Apogee: Nov. 13 at 3:26.....404,350 km.
 Perigee: Nov. 26 at 2:23.....369,863 km.

universal time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times given in The Backyard Astronomer are UT unless noted. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska and Hawaii, 10. For example, if an event is to happen at 03:00 hours UT on February 2, then EST for the event is 10 p.m., February 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m, March 4.

Although easily visible in the morning sky, Mars is smallish in the eyepiece. When the Red Planet was near opposition in 1982, Jean Dragesco took its picture with a 14-inch SCT, focal projection at f/80, and a 2-second exposure. South is up; Syrtis Major is at top right and a white cloud can be seen over Elysium (lower left).

Jupiter and Uranus; conjunction with the Sun is on December 21st.

Meteors

Three meteor showers are due this month: the Taurids (which peak on the 5th), the Andromedids (on the 14th), and the Leonids (on the 18th). The Taurids are generally slow and bright, with many fireballs. The hourly rate is about 10, and the radiant lies in the Pleiades/Hyades area.

The Andromedids are also slow and bright, but sparse — 5 to 10 per hour. The radiant lies to the northeast of M-31.

The Leonids have their radiant in the "Sickle" of Leo, and usually produce some 10 to 20 very swift and bright meteors per hour. This shower is renowned for its occasional "storms" — showers in which as many as several hundred meteors come flashing every minute. These occur typically at 33-year intervals — the last was 1966; the next will (probably) occur in 1998 or 1999.

The Moon will interfere a little with the Taurids, somewhat more with the Andromedids, and rather severely with the Leonids.

close-up on pegasus

Culminating during the early evening in November is **Pegasus**, the most commanding of the autumn constellations. The Winged Horse, one of the largest star groups, covers over 1,100 square degrees; its famous asterism, the Great Square — formed by Alpha (α), Beta (β), and Gamma (γ) Pegasi and Alpha (α) Andromedae — is a landmark of the sky. Yet for all its area, it doesn't contain many deep-sky objects, or bright ones at least. It is a window of space that opens on the realm of the galaxies, most of which are faint, fuzzy, and difficult to see. Practically the only bright "local" objects in Pegasus are double and variable stars. But if you have a telescope of 6-inch or more aperture you'll have plenty to look at on dark nights in and around the Great Square.

The best deep-sky object in Pegasus is globular cluster **M-15** (NGC-7078), a sixth-magnitude globe of suns 4° northwest of the star Enif. Although at 12' across it is not the largest globular, it is the 12th brightest in the entire heavens and one of the finest examples in the northern sky. A 2.4-inch scope shows it as a grainy spot at low power, and a 4-inch begins to show mottled partial



satellites of jupiter

0:00 UT

1	4201	.	•	•	16	43102	•	•	•
2	43102	.	•	•	17	43021	•	•	•
3	4301	.	•	•	18	43210	.	•	•
4	4230	.	•	•	19	401	.	•	•
5	4023	.	•	•	20	4023	.	•	•
6	40123	.	•	•	21	4103	.	•	•
7	2103	.	•	•	22	42013	.	•	•
8	20314	.	•	•	23	41302	.	•	•
9	31024	.	•	•	24	30412	.	•	•
10	40213	.	•	•	25	32104	.	•	•
11	32104	.	•	•	26	2014	.	•	•
12	034	.	•	•	27	0324	.	•	•
13	0234	.	•	•	28	034	.	•	•
14	1043	.	•	•	29	20134	.	•	•
15	2031	.	•	•	30	1024	.	•	•

Jupiter = 0, Io = 1, Europa = Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)



resolution around the group's edges. An 8-inch telescope at high power shows hundreds of grainy stars against a pitch black background, some spilling out of the field in pairs and triplets. Larger telescopes show progressively better views.

As globular clusters go, M-15 is unusual for its high percentage of variable stars; it contains 112 of them, most of which are short-period RR Lyrae-type stars fainter than 16th magnitude. Another quirk of M-15 is that a small planetary nebula,

K648, lies within the group. It is faint — about 14th magnitude — and consequently impossible to pick out visually from the myriad of stars surrounding it. In 1974 astronomers identified M-15 as a powerful X-ray source, indicating either that it is filled with supernova remnants or that it contains a massive black hole at its center. About 130 light-years from end to end, M-15 lies at a distance of 34,000 light-years from Earth.

Another Milky Way object, the star **Enif** (Epsilon [ε] Pegasi) is a type K2 supergiant whose luminosity is about 5,800 times that of our Sun. Enif's mass is about 10 times the Sun's, and it glows at magnitude 2.3 in our skies. Thus it lies at a distance of about 780 light-years. Just over an arc-minute away is an 11.5 magnitude companion star at position angle 325°. This star is not physically associated with Enif; it is just a chance optical alignment.

A physically associated binary system is **37 Pegasi**, a close pairing of sixth and seventh-magnitude stars with a maximum separation of only 1.1". It is a rather difficult duo to split, so wait until steady seeing prevails and use high power; a 6-incher at 300x should easily separate the two. The pair lies at a distance of 165 light-years, and the distance between the two stars is about 40 astronomical units — the same as Pluto's average orbital distance.

Several fine variable stars lie in Pegasus, one of which is **Scheat** (Beta [β] Pegasi),

Above: From Grande Prairie, Alberta, George LaFluer recorded this spectacular auroral display cascading downward from the stars of Cygnus and Lyra. **Right:** With a 6-inch f/16 Maksutov scope, Jacques Guertin photographed a very old waning Moon last August 6. He used 25 ASA film and a one-second exposure.

an irregular red giant of spectral type M2. About five times as massive as the Sun, Scheat measures about 160 times the Sun's diameter and is thus only one millionth as dense as Sol. Scheat lies at a distance of 210 light-years, and is moving away from us at a rate of five miles per second. This reddish sun quite unpredictably varies from magnitude 2.1 to 3.0, so try observing over a period of a few weeks, comparing it to nearby stars of known brightness. Who knows what variations you may find!

Another variable in Pegasus is **AG Pegasi**, a curious star located about 3° northeast of Enif. This highly erratic star became important in 1894 when W. Fleming, working at Harvard, discovered bright hydrogen lines in its spectrum. A check of early records revealed that AG Peg was a normal ninth-magnitude object up until 1850, when it started brightening. By 1870 it had become a sixth-magnitude star, visible to the naked eye. It remained stable until 1920, when a series of remarkable changes started; two years

totality ending for epsilon aurigae

The eclipsing binary Epsilon (ε) Aurigae has been at minimum light since December 1982. According to predictions, this "total stellar eclipse" will last until January 1984, when the star will begin its return to full light, scheduled to be reached in May 1984. (See "Mystery Star," *ASTRONOMY*, August 1983).

Anyone interested in observing this rare event — the eclipses occur at 27-year intervals — should compare Epsilon's brightness once a week relative to its neighbors Zeta (ζ), at 3.8 magnitude, and Eta (η), at 3.2 magnitude. In eclipse, Epsilon is at 3.8 magnitude, but starting sometime in January, you ought to see it begin to change. By late spring, it will reach its normal 3.0 magnitude brightness.





Jack Newton used a 16-inch f/5 Newtonian telescope and 400 ASA emulsion to make this image of galaxy NGC-7479, a barred spiral in Pegasus. The galaxy has a low surface brightness, but can be picked up as a circular haze even in 4-inch scopes. It is one of several Pegasus objects discussed in this month's Close-up.

later it displayed characteristic signs of being what is now termed a "symbiotic" variable. Such a star is composed of two dissimilar kinds of stars that "need" each other and show nova-like spectral features superimposed on a normal late-type spectrum. In 1967 astronomers found that the system is probably composed of an M3 giant and a Wolf-Rayet star (one that resembles the nucleus of a planetary nebula). The similar stars R Aquarii and FG Sagittae show optically visible nebulosity. In 1961 the star's total light equalled magnitude 8.5; it is probably fading very slowly.

There is one open star cluster in Pegasus, although it may not be a physical grouping. **NGC-7772** consists of a loose arrangement of seven stars between magnitudes 11 and 14; it looks like a smaller, fainter version of M-73 in Aquarius. NGC-7772 spans only 1.6'

across, and appears as a tiny hazy spot in 4-inch telescopes. An 8-inch scope shows a grainy patch with a few stars, but it is not an impressive sight.

You really wouldn't expect to find good open clusters in Pegasus since it lies away from the central plane of our Galaxy. But you *would* expect to find galaxies, and indeed you can. The best galaxy in Pegasus is the highly inclined Sb-type spiral **NGC-7331**, easily visible in 3-inch telescopes as an elongated 10th magnitude patch of light. It is located 4.3° north and slightly west of Eta (η) Pegasi, measures 10' x 3', and shows a great amount of detail in long exposure photographs. A good 6-inch telescope shows a bright oval core surrounded by a faint mottled haze, whereas a 10-inch begins to show some dark lane structure and a tiny stellar nucleus.

When you look at NGC-7331, bear in

mind that astronomers Geoffrey and Margaret Burbidge and Vera Rubin studied this system extensively, describing it as "similar in structure and type to the Andromeda Galaxy but 23 times as distant." Thus NGC-7331 lies about 50 million light-years away, and the galaxy's total mass is probably about 140 billion solar masses. In 1959 a bright (13th magnitude) supernova appeared in the galaxy's arms.

About half a degree south-southwest of NGC-7331 lies a curious group of galaxies called **Stephan's Quintet**. This object consists of four physically associated galaxies — NGC-7317, NGC-7318A, NGC-7318B, and NGC-7319 — and one galaxy much closer to us but in the same line of sight, NGC-7320. At 14th magnitude, NGC-7320 is the brightest along with NGC-7319, and the other three are 15th magnitude objects. The group is a difficult target for amateur telescopes but can be picked up as a faint haze in an 8-inch telescope under ideal conditions. A 16-inch telescope shows the group quite well, including condensed nuclei and faint outer haloes around the galaxies.

Several more galaxies lie in the constellation, all of which are faint and require at least a 4-inch telescope to detect. **NGC-7217** is a face-on Sb-type spiral that measures 3' across and glows at magnitude 11.3. Most backyard telescopes show this object as a circular haze with a slightly brighter middle. Apertures of 16 inches or more reveal a tiny stellar nucleus with a faint star on the galaxy's northern edge. **NGC-7479** is a 12th magnitude barred spiral about the same size as 7217; 8-inch scopes show an elongated blur of light, while 16-inchers show a stellar nucleus and faint haze representing the galaxy's spiral arms. Slightly smaller than 7479 but just as bright is **NGC-7448**, an Sc-type galaxy that shows in 8-inch instruments as an elongated patch with a condensed middle region. **NGC-7741** is a 12th magnitude barred spiral measuring 3.1' x 2.5'. It appears as a smudge of nebulosity in an 8-inch at medium powers. Slightly smaller is **NGC-7814**, an Sa/Sb-type edge-on galaxy that shows a dark lane in 16-inch and 20-inch telescopes.

Although it doesn't contain many bright "showpiece" deep-sky wonders, the constellation Pegasus is clearly a fine hunting ground for challenging galaxies and a number of erratic stars. Standing out under the stars this fall, the familiar Great Square will be the dominant sight; don't let the famed Winged Horse slip by your telescope.

M-15

8-inch
100X

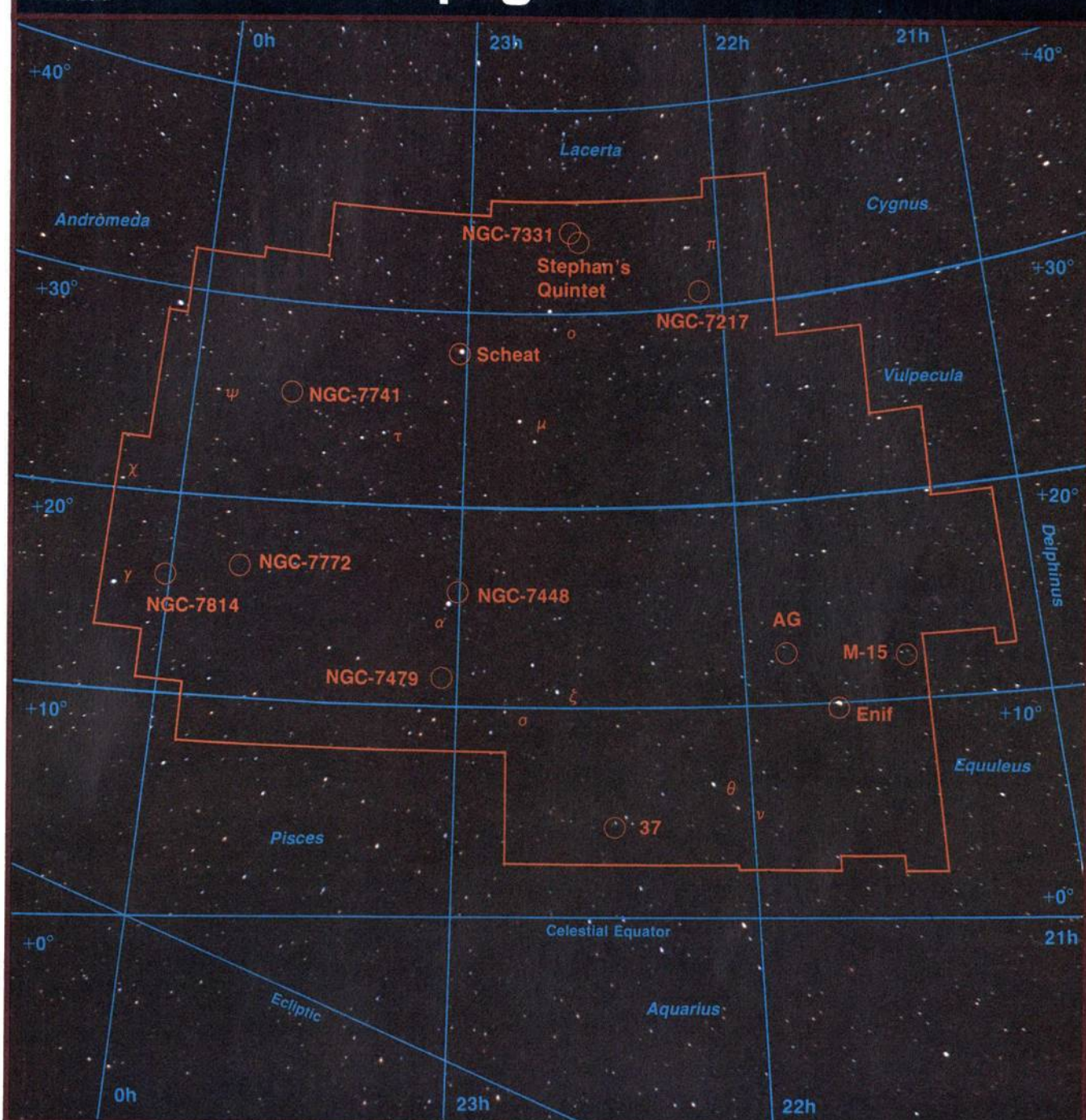


NGC-7331

8-inch
50X



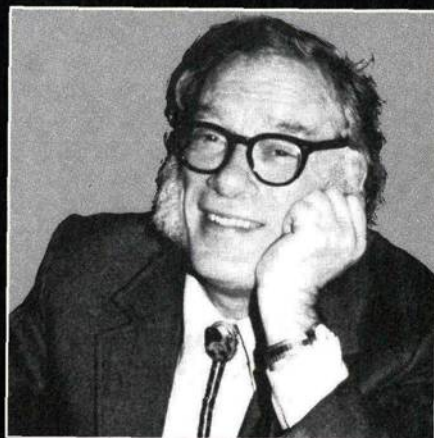
Sketches by
David J. Eicher



Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (2000)	Dec.
M-15	●	6.5	15'	21h 28m	+11°57'	21h 30s	+12°10'
Enif	★	2.3	—	21h 42m	+09°39'	21h 44s	+09°53'
AG	IV	6.4↔8.2	Irr	21h 49m	+12°23'	21h 51s	+12°37'
NGC-7217	§	11.3	3'x2'	22h 06m	+31°07'	22h 08s	+31°22'
37	★ ²	5.8,7.0	1"	22h 28m	+04°11'	22h 30s	+04°26'
Stephan's Quintet	§	14.0	group	22h 35m	+33°40'	22h 37s	+33°56'
NGC-7331	§	10.4	10'x2'	22h 35m	+34°10'	22h 37s	+34°26'
NGC-7448	§	11.8	2'x1'	22h 59m	+13°43'	23h 00s	+15°59'
Scheat (β)	IV	2.1↔3.0	Irr	23h 01m	+27°49'	23h 04m	+28°05'
NGC-7479	§	11.8	3'	23h 02m	+12°03'	23h 05s	+12°19'
NGC-7741	§	12.1	3'	23h 41m	+25°48'	23h 44s	+26°05'
NGC-7772	○	11.0	2'	23h 49m	+15°59'	23h 52s	+16°16'
NGC-7814	§	12.0	5'x1'	00h 01m	+15°51'	00h 03s	+16°08'

- ★ Star
- ★² Double Star
- ★³ Triple Star
- RV Regular Variable
- SRV Semi-Regular Variable
- IV Irregular Variable
- EV Eclipsing Variable
- Open Cluster
- Globular Cluster
- Planetary Nebula
- Bright Diffuse Nebula
- 0 Elliptical Galaxy
- § Spiral Galaxy
- § Barred Spiral Galaxy
- # Peculiar/Irregular Galaxy

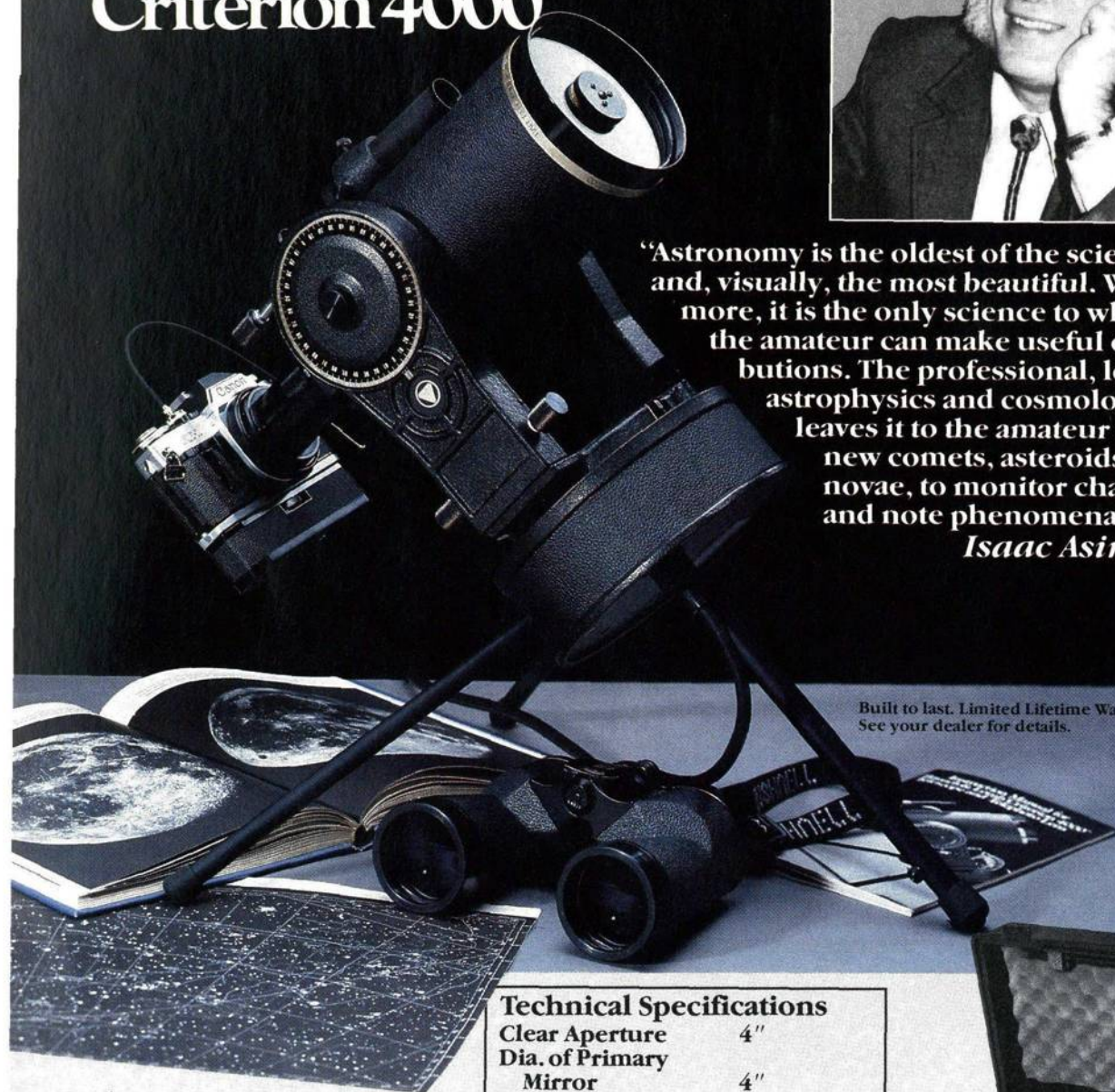
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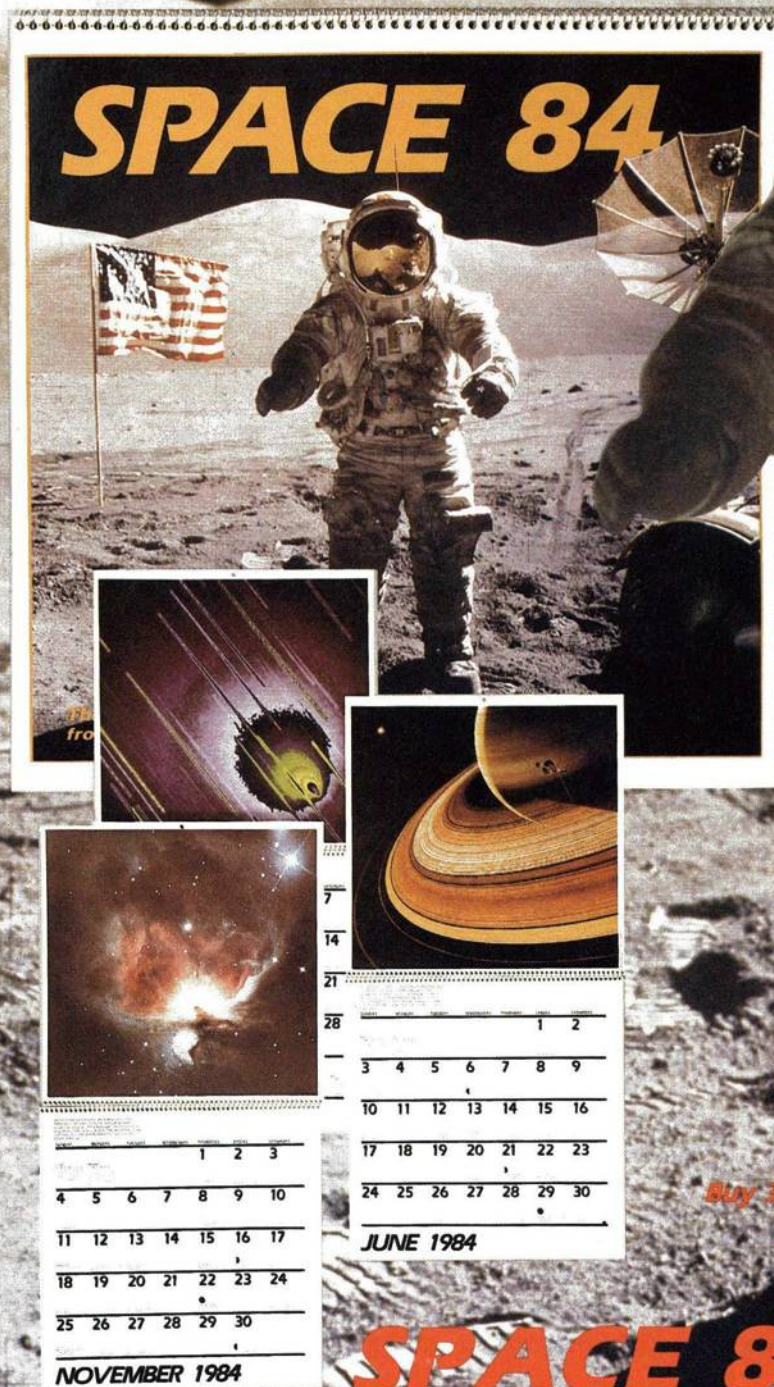
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